Vol. XXIII. JANUARY, 1897. No. 1.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publication.

CONTENTS.

SOCIETY AFFAIRS.

PAPERS.

ILLUSTRATIONS.

The price of publications is as follows: Proceedings, $6 per annum; Transactions, $10 per annum. Postage will be added when they are sent to foreign countries.

American Society of Civil Engineers.

OFFICERS FOR 1897.

President, BENJAMIN MORGAN HARROD.

Vice-Presidents.

Term expires January, 1898:
WILLIAM R. HUTTON,
P. ALEXANDER PETERSON.

Term expires January, 1899:
GEORGE H. MENDELL,
JOHN F. WALLACE.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOHN THOMSON.

Directors.

Term expires January, 1898:	*Term expires January*, 1899:	*Term expires January*, 1900:
AUGUSTUS MORDECAI,	GEORGE A. JUST,	JAMES OWEN,
CHARLES SOOYSMITH,	WM. BARCLAY PARSONS,	RUDOLPH HERING,
GEORGE H. BENZENBERG,	HORACE SEE,	HENRY G. MORSE,
GEORGE H. BROWNE,	JOHN R. FREEMAN,	BENJAMIN L. CROSBY,
ROBERT CARTWRIGHT,	DANIEL BONTECOU,	HENRY S. HAINES,
FAYETTE S. CURTIS.	THOMAS W. SYMONS.	LORENZO M. JOHNSON.

Assistant Secretary, JOHN M. GOODELL.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
HORACE SEE,	JOHN THOMSON,	AUGUSTUS MORDECAI,
WM. BARCLAY PARSONS,	ROBERT CARTWRIGHT,	DANIEL BONTECOU,
F. S. CURTIS,	RUDOLPH HERING,	CHARLES WARREN HUNT,
JOHN R. FREEMAN,	JOHN F. WALLACE,	WM. BARCLAY PARSONS,
JAMES OWEN.	HENRY S. HAINES.	HENRY G. MORSE.

Special Committees.

ON UNIFORM STANDARD TIME:—Sandford Fleming, Charles Paine, Theodore N. Ely, J. M. Toucey, T. Egleston.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf, Thomas Rodd, A. E. Hunt.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—127 EAST TWENTY-THIRD STREET, NEW YORK.

Vol. XXIII. JANUARY, 1897. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

January 6th, 1897.—The meeting was called to order at 20.15 o'clock, President Thomas Curtis Clarke in the chair; Charles Warren Hunt, Secretary, and present, also, 97 members and 16 visitors.

Minutes of the meetings of December 2d and 16th, 1896, were approved as printed in *Proceedings* for December, 1896.

A paper entitled, "The Underpinning of Heavy Buildings," was presented by Jules Breuchaud, Assoc. Am. Soc. C. E., and discussed by Messrs. T. C. Clarke, John Bogart, Henry B. Seaman, Charles E. Emery, F. W. Skinner, J. F. O'Rourke, J. N. Greene and the author. The Secretary read written discussions on the subject from Messrs. Alfred Noble, A. A. Schenck and T. Kennard Thomson.

Ballots were canvassed and the following candidates declared elected:

As Member.

Frederick Humphreville Lewis, Philadelphia, Pa.

As Associate Members.

Juan Abella, London, England.
Frank Lloyd Averill, Washington, D. C.
Edwin Clark, Philadelphia, Pa.
Spencer Baird Newberry, Sandusky, O.

The Secretary announced the election on January 5th, 1897, by the Board of Direction of the following candidates:

As Juniors.

Jaquelin Marshall Braxton, Jacksonville, Fla.
Robert Hoyt, Katonah, N. Y.
Ely Morgan Talcott Ryder, New Haven, Conn.
Gratz Brown Strickler, Washington, D. C.

The Secretary read the programme for the Forty-fourth Annual Meeting.

Adjourned.

FORTY-FOURTH ANNUAL MEETING.*

January 20th, 1897.—The meeting was called to order at 10.20 o'clock, President Thomas Curtis Clarke in the chair; Charles Warren Hunt, Secretary, and present, also, about 260 members and a number of visitors.

Messrs. M. T. Jefferis, B. J. Burke and W. T. Brown were appointed tellers to canvass the ballots for officers for the ensuing year.

The Annual Report† of the Board of Direction for the year ending December 31st, 1896, and the Annual Reports of the Treasurer, the Secretary acting as Auditor, and the Finance Committee, were presented, and, on motion, duly seconded, the report of the Board of Direction was accepted.

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* A full report of the Forty-fourth Annual Meeting will be published in a subsequent number of *Proceedings*.

† See pages 9 to 24 for the Annual Reports of the Board of Direction, the Secretary acting as Auditor, and the Finance Committee.

The Secretary read the following report of the Board of Censors to award the Norman Medal:

Report of the Award of the Norman Medal, 1895-96.

BUFFALO, December 30th, 1896.

The Board of Censors appointed to award the Norman Medal for papers published during the year ending August 1st, 1896, begs to report that it awards the medal to Paper No. 764, entitled, "What is the Life of an Iron Railroad Bridge?" by J. E. Greiner, M. Am. Soc. C. E.

W. G. CURTIS,
A. P. BOLLER,
THOMAS W. SYMONS.

Secretary read the following report of the Committee to award the Rowland Prize:

Report of the Award of the Rowland Prize, 1895 96.

BOSTON, December 23d, 1896.

The Committee appointed to award the Rowland Prize for the year ending August 1st, 1896, begs leave to report that it has awarded this prize to Henry St. Leger Coppée, M. Am. Soc. C. E., for paper No. 775, entitled, "Bank Revetment on the Lower Mississippi."

J. F. WALLACE,
HOWARD A. CARSON,
CHAS. WARREN HUNT.

A report of the canvass of votes received for the place for holding the next Annual Convention was read by the Secretary, and the whole matter was referred to the Board of Direction, with power.

The Secretary read a letter from Charles B. Dudley, M. Am. Soc. C. E., Chairman of the Sub-Committee, of the American Society of Civil Engineers, of the International Committee on Standards for the Analysis of Iron and Steel, reporting progress.

The Secretary stated for George M. Bond, M. Am. Soc. C. E., Chairman of the Committee on Units of Measurement, that the Committee desired to report progress.

The Secretary read the following report of the Board of Direction:

Report of the Board of Direction in the Matter of the Proposed Appointment of a Special Committee to report on the Proper Manipulation of Tests of Cement.

At a business meeting of the Society, held November 4th, 1896, it was unanimously voted, in accordance with Article VI, Section 13, of the Constitution, to recommend to the Board of Direction the consideration of the appointment of a committee to report on the proper manipulation of tests of cement.

It is quite evident that a committee appointed under this resolution would be concerned only as to the manner and method of making tests, and it would not be required to go into a general consideration of cements or cement specifications. It is a generally admitted fact that although a special committee of the Society reported to the Society in 1885 certain rules and regulations on this subject, nevertheless, the development of the cement industry, and the more general use of the material, has already caused those rules, although excellent at the time, to be now short of modern requirements. Under these rules it is possible for different experimenters to get widely different results, and such a state of affairs works not only to the detriment and disadvantage of the honest manufacturer, but also to the engineer user of the material.

Your Board has carefully considered this question and finds the following reasons in favor of appointing such a committee as is proposed by the resolution of the Society:

First.—That the methods of tests now known to the world as the standard of the American Society of Civil Engineers, while excellent at the time they were adopted by the Society, are not the best possible now and should be brought to conformity with present knowledge and the latest experience of this country and of Europe.

Second.—That a method of making tests should be so devised and specified in detail as to eliminate as far as practicable the personal element of the tester, in order that the test may more certainly represent the true character of the cement tested. It is a constantly recurring experience with cement manufacturers and users that tests giving unsatisfactory results are, after embarrassing delays and disputes, found to be unfair or incompetent because of some peculiarity in the manipulation. Methods of mixing and making briquettes and conducting the tests which would make these now variable factors uniform in all cases would save a vast amount of time, trouble and expense. If the end desired can be accomplished and the tests of cements like those of metals be made to represent uniformly and truly the strength of the cement tested, the defects and virtues shown by tests will in every case be due to qualities dependent upon chemical constitution, methods of manufacture or treatment, and improvement in these latter would be more easy to discover and make.

The reasons in opposition to the appointment of such a committee appear to be:

First.—That it is inadvisable for the Society to adopt standards of any kind; that such work is better done when left to individuals.

Second.—That in the case in question it is doubtful whether it is possible to adopt any methods of preparing and testing briquettes whereby the personal equation can be reduced to a negligible quantity.

Your Board, however, is of the firm opinion that the reasons in favor of appointing the committee outweigh those in opposition. especially in view of the fact that a committee of the Society has already promulgated rules in this matter, which, for the reputation of the Society, should be kept at the highest attainable standard or else revoked.

It seems probable from what has been already said and written concerning the appointment of the proposed committee, that an effort may be made to reopen the entire subject of cement tests as considered by the former committee of the Society, and not confine the work to the simple matter of proper manipulation of tests. Your Board has given some attention to this matter, and is strongly of the opinion that the duties of the proposed committee should not be changed from those outlined in the resolution. Many and continuous efforts are being made in Europe by cement manufacturers and others, by concerted as well as individual action, to arrive at some uniform requirements which shall become the standard specifications for cements. But as yet no uniform specification has been decided upon, and the problem is probably a more difficult one in this country than it is in Europe. It does not seem at the present time to be advisable to have a rigid set of specifications for cements in this country, where the character of the different products manufactured will necessarily vary with the materials available for use in the different regions, and where the whole process of manufacture is in a course of development which would apparently be rather dwarfed and confined than benefited by a set of specifications put forward by the American Society of Civil Engineers, to apply to the whole country.

By order of the Board of Direction.

Chas. Warren Hunt,

Secretary.

President Clarke read Article VI, Section 13, of the Constitution, and after discussion by Messrs. Foster Crowell, S. Whinery, R. W. Lesley and E. P. North, it was unanimously voted, on motion duly seconded, to have the Board of Direction issue a letter ballot.

The Secretary presented for S. C. Thompson, M. Am. Soc. C. E., the following preamble and resolution:

"In consideration of the fact that the engineering profession and the people of this country have no legal protection against any incompetent or unscrupulous person who chooses to advertise or sign himself with the title of Civil Engineer, thereby reflecting upon and injuring the entire profession, and in consideration of the fact that it has been found advantageous in most States to grant legal protection to members of the legal and medical professions; therefore, be it

"*Resolved*, That the American Society of Civil Engineers places itself on record as favoring judicious legal restrictions against the unauthorized and improper use of the title of Civil Engineer."

Upon motion, duly seconded, the matter was laid on the table.

Recess was taken from 11.15 to 12 o'clock.

On reassembling after the recess, the tellers presented the following report:

Report of the Tellers Appointed to Count the Vote for Officers, January 20th, 1897:

JANUARY 20TH, 1897.

The tellers appointed to canvass the ballots for officers of the Society respectfully report that they have performed the duties assigned to them, and the count is as follows:

Total number of votes cast		466
Not entitled to vote	3	
Without signature	6	
		9
Total number of votes counted		457

For President:

Benjamin Morgan Harrod	457

For Vice-Presidents:

George Henry Mendell	457
John Findley Wallace	453
Alfred Noble	1
Rudolph Fink	1
Daniel Bontecou	1
William H. Kennedy	1

For Treasurer:

John Thomson	457

For Directors, to serve three years:

District No. 1.—Rudolph Hering		455
	J. James R. Croes	1
	John C. Trautwine, Jr.	1
District No. 1.—James Owen		455
	Joseph P. Davis	1
	George H. Blakeley	1
District No. 4.—Henry G. Morse		457
District No. 6.—Benjamin L. Crosby		456
	John A. Ockerson	1
District No. 7.—Henry S. Haines		457
	Lorenzo M. Johnson	456
	James D. Schuyler	1

Respectfully submitted,

M. T. Jefferis,
B. J. Burke,
Walter T. Brown.

The President announced that the following officers were elected:

President, to serve one year:

Benjamin Morgan Harrod, New Orleans, La.

Vice-Presidents, to serve two years:

George H. Mendell, San Francisco, Cal.
John F. Wallace, Chicago, Ill.

For Treasurer, to serve one year:

John Thomson, New York City.

For Directors, to serve three years:

District No. 1.—James Owen, Newark, N. J.
Rudolph Hering, New York City.

District No. 4.—Henry G. Morse, Wilmington, Del.

District No. 6.—Benjamin L. Crosby, St. Louis, Mo.

District No. 7.—Henry S. Haines, Atlanta, Ga.
Lorenzo M. Johnson, Eagle Pass, Tex.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 5th, 1897.—Seven members present.

Action was taken authorizing the President and Secretary to sign contract for the erection of the New Society House.

The matter of the appointment of a Special Committee of the Society to report on the proper manipulation of tests of cement, referred to the Board by action of the Society at the meeting of November 4th, 1896, was considered, and a report adopted for presentation to the Society at the Annual Meeting.

The Secretary reported the attendance at the Library on the evenings during the months of November and December, 1896, and it was decided that for the present the opening of the Library every night should not be continued, but that it should be opened as heretofore on each Wednesday evening.

The Annual Report of the Board of Direction for presentation to the Society was adopted.

Applications were considered and other routine business transacted.

Four candidates were elected as Juniors.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1896.

PRESENTED AT THE ANNUAL MEETING, JANUARY 20TH, 1897.

The Board of Direction, in compliance with the provision of the Constitution of the Society, presents its report for the year ending December 31st, 1896.

MEMBERSHIP.

The changes in membership are shown in the following table:

	Jan. 1, 1896.			Jan. 1, 1897.			Losses.				Additions.		Totals.	
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	By Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.
Honorary Members......	4	4	8	4	4	8	..	..	....	....	....	....	....	...
Corresponding Members.	....	3	3	....	3	3	..	..	....	....	....	....	....	...
Members	218	1 022	1 240	231	1 021	1 252	..	10	8	18	*25	48	36	73
Associate Members.......	56	181	237	70	212	282	19	2	....	2	†20	49	23	69
Associates	23	51	74	29	55	82	1	..	....	1	....	9	2	9
Juniors.................	90	188	278	105	213	318	25	3	1	2	....	46	31	46
Fellows.................	13	34	47	9	32	41	..	..	....	6	....	...	6	...
Subscribers.............	7	26	33	5	27	32	..	..	....	1	..	....	1	...
Totals..............	411	1 509	1 920	451	1 567	2 018	45	15	9	30	45	152	99	197

* 19 Associate Members, 1 Associate, 5 Juniors. † 20 Juniors.

It will be seen by the table that the net increase during the year has been 98.

The total number of applications considered by the Board during the year has been 206.

Action has been taken as follows:

Passed to ballot as Member........................	69
Passed to ballot as Associate Member...............	64
Elected Associate..................................	7
Elected Junior	50
Total	190
Awaiting action	58

The losses by death during the year number 30. They are as follows.—Eighteen Members: Job Abbott, William Albert Allen, David Leonard Barnes, Max Joseph Becker, Louis Provost Evans, Francis Renatus Fava, Jr., William Harrison Grant, Robert Lewis Harris, John Houston, Robert Neilson, Norman James Nichols, Albert Franklin Noyes, James Clarence Post, Andrew Jackson Post, Joseph Russell Thomas, Christopher C. Waite, Orlando Belina Wheeler, John Allston Wilson. Two Associate Members: Francis Asbury Lyte, James Hugh Stanwood. One Associate: Waterman Stone. Two Juniors: Vernon Hill Gridley, John Joseph Tallon. Six Fellows: Charles Lewis Colby, Alexander Samuel Diven, Francisco de Garay, James F. Joy, McRee Swift, Thomas Prosser. One Subscriber: George H. Nettleton.

Library.

The following sums have been expended upon the library during the year:

Binding 35 volumes	$53 10	
Purchase of books	12 75	
Contingent expenses	4 75	
Total		$70 60
Total of previous year		70 58

The additions to the library from all sources have been:

Bound volumes	188	
Unbound volumes	269	
Pamphlets	361	
Maps, photographs and charts	234	
Specifications	26	
Total additions during the year		1 078
The present number of titles in the library is		20 741

Donations.

Under the will of the late McRee Swift, F. Am. Soc. C. E., a bequest of one thousand dollars ($1 000) was received in June, 1896, to be invested and the income to be devoted to the purchase of rare books and maps for the Library of the Society, and models for its museum. This bequest was made by Mr. Swift, who was one of the charter members of the Society, in memory of his father, "General Joseph G. Swift, born in 1783, died in 1865, the first graduate of the Military Academy at West Point, afterwards Chief of the Corps of Engineers, U. S. A., and subsequently to his resignation from the army, Chief Engineer of many undertakings, among them the New Orleans and Pontchartrain Railroad in 1829, and the Harlem Railroad in 1832."

In previous reports of your Board attention has been called to the fact that the growth of the Library is largely dependent upon legacies

and upon contributions of reports and other engineering literature from members, corporations and others who take an interest in the Society's welfare, and while the appreciation of the Society for this legacy from one of its oldest members has already been expressed, your Board desires in again referring to this subject to emphasize the gratification it feels in this thoughtful provision for the benefit of posterity made by one, who, although he some years before his death ceased to be an active member of the Society and of the profession, maintained to the end his interest in both.

Society House.

The expenditure for repairs and betterments of the Society House has been $92 48.

The rooms have been kept open on Wednesday evenings during the year.

During the months of November and December the experiment was tried of opening the library every evening for the convenience of the membership.

The attendance was as follows:

Number of evenings open	45
Total attendance	36
Greatest number attending on any one evening (once)	4
Number of evenings when only one came	15
Number of evenings when no one came	22

Exclusive of the attendance at meetings, 1 172 members and others consulted the library during the year.

New Society House.

The purchase of the site for the New Society House, at Nos. 218 and 220 West Fifty-seventh Street, was reported by your Board a year ago. The price paid was $80 000, $20 000 of which was paid in cash, and the balance, $60 000, left on mortgage. In March, 1896, it was decided to secure plans by instituting a competition open to all architects connected with the Society, and to a limited number of architects not so connected. Twelve designs were received, and that of Mr. C. L. W. Eidlitz selected. Members of the Society are familiar with this design, it having been reproduced in a circular issued in May, 1896. During the spring and summer the plans and specifications were perfected, but owing to the impossibility of securing a loan on favorable terms, proposals for the erection of the building were not asked for until after the Presidential election. Pending this, however, the vault privilege, 1 500 sq. ft., was acquired from the city for $937 50 and the lots were excavated at a cost of $4 500. Meanwhile, also,

negotiations were in progress for securing the necessary loan, and in November the Finance Committee was enabled to report an arrangement by which all the funds necessary for completing the new house could be secured from the Mutual Life Insurance Company on most favorable terms.

After the receipt of competitive bids the contract for the erection of the building complete was let early in December to Mr. Charles T. Wills for $86 775, which, with the cost of excavation, already paid, makes the total $91 275, a sum only slightly in excess of that mentioned in last year's report as the probable cost. Work has been started, and it is expected that the building will be completed on or before October 1st, 1897.

The loan arranged for will provide all the funds to finish the work, and it will therefore not be necessary to dispose of the present house until a favorable opportunity offers, at which time the debt can be considerably reduced.

Two circulars have been issued by the Board asking for subscriptions which have resulted in a total subscription of $19 170 from 277 persons, and $17 480 of this amount has been paid.

Attention is called to the fact that to date $32 362 70 in all has been expended on the new house, and, as only $17 480 has been received in cash subscriptions, it follows that $14 882 70 has already been furnished for this purpose out of the savings of the past few years. It is submitted that this fact demonstrates the financial ability of the Society to carry the work to a successful conclusion.

Inasmuch, however, as, even with the strictest economy, there will still remain a debt upon the new house when completed, your Board hopes that those persons who have deferred subscribing until the project was placed on an assured basis, will now come forward and aid in the reduction of this debt.

It is believed, also, that most of the 1 741 members who have not as yet subscribed have failed to do so in large measure owing to the hard times, and not to lack of interest in the project, and that, the work of construction being in progress, there are many who, under present financial conditions, would be glad to give at least a small sum if the matter were brought to their attention. With this in view, the Secretary has prepared a sketch of the history of the Society which will be presented at the Annual Meeting, and has collected a nearly complete set of portraits of the past officers for reproduction. Your Board, believing that the membership will be much interested in this work, has decided to publish it in a volume, to be sold only on subscription, at a price which will leave a handsome profit to be devoted to the New Society House Fund. The volume will be printed in the best manner, and will contain thirty-five half-tone reproductions of portraits of past officers; will be bound in full morocco, and generally

designed with a view of making a book which every person connected with the Society will be glad to have in his library. It will be ready for distribution early in February.

Publications.

During the year a new system of publication has been in use. The Society publications, now, as heretofore, consist of *Proceedings* and *Transactions*, but with these changes: *Proceedings* are issued regularly on the fourth Wednesday of each month, except June and July, and contain advance copies of all papers to be presented, the record of the work of the Society, memoirs of deceased members, etc. *Transactions* are issued in volumes, which may be secured by members in standard cloth or half morocco bindings at a price covering their cost. This has been much appreciated by members. Three hundred copies of Volume XXXV were issued in binding, and 500 bindings have been ordered for future volumes.

During the year an earnest effort was made to secure sketches of the lives of deceased members of whom no memoir had been published. In many instances this was found very difficult, but since January 1st, 1896, 54 memoirs have been published, of which 44 were of men whose death occurred before that date. Many other memorial notices are in various stages of preparation, and it is hoped in the near future the list of these publications will be complete. It has been decided that hereafter all memoirs will be published in *Proceedings* and also subsequently reproduced in the volumes of *Transactions*.

The exchange and free lists have been carefully considered during the year, and the Society publications are now sent to 120 exchanges and to 24 colleges, libraries, etc. The number of extra copies sent under an old agreement with subscribers to the first building fund has been reduced 30% by consent of the subscribers. In all, 166 copies of the Society publications have been sent during the year in addition to the membership list, and to the list of subscribers, which now numbers 25.

The following table gives in detail a summary of the publications issued during 1896:

	Number issued.	Total edition of each number.	Number of pages.	Plates.	Cuts
*Transactions**	2	2 400	1 169	21	130
*Proceedings**..........	10	2 350	926	17	103
Index Vols. XXVIII to XXXV............	1	2 400	70	..	....
Constitution and List of Members..........	1	2 600	186	..	....
Advertisements........	10	2 350	120	..	....
Totals	..	....	2 471	38	233

* Includes Indexes and Tables of Contents.

The cost of publications has been :

For Paper, Printing, Binding *Transactions* and *Proceedings*..		$6 529 49
For Plates and Cuts		826 57
For Copyright, Wrappers and Sundry Expenses charged to Publications		129 62
For Commission on Advertisements		266 75
For 5 250 Extra Copies of Papers		321 71
For 400 Extra Copies of Memoirs.		18 90
For List of Members		717 01
For Index to *Transactions*, Vols. XXVIII to XXXV.		220 08
Total		$9 030 13
For time of Officers, Clerks and Stenographers, charged to Publications		3 049 83
Total		$12 079 96
Deduct amount received for Advertisements	$1 863 30	
Deduct amount received for Sale of Publications.	1 421 62	
		3 284 92
Net cost of Publications		$8 795 04
Net cost of Publications for 1895 (see Report of the Board of Direction, January, 1896)		8 274 24

ALL PUBLICATIONS (CHARGES FOR TIME OF EMPLOYEES EXCLUDED).

	1894.	1895.	1896.
Total pages published	1 748	2 008	2 471
Total cost, including illustrations	$10 876 81	$9 745 03	$9 030 13
Edition of *Transactions*	2 200	2 300	2 400
Edition of *Proceedings*			2 350
Average cost per page	$6 22	$4 85	$3 65

MEETINGS.

The Annual Meeting, held in New York, January 15th and 16th, 1896, was attended by 150 of the Society members and a number of visitors.

The attendance at the Twenty-eighth Annual Convention, held in San Francisco, Cal., was 62 members and 67 guests.

Eighteen regular meetings have been held at the Society House, at which the attendance has on several occasions exceeded 150, the average being 85.

Twenty-five formal papers were presented at these meetings. In the oral discussion 104 persons took part, and correspondence from 118 was read.

Society Badge.

Total number of old-style badges issued	1 051	
" " " " returned	39	
Number of old-style badges now out		1 012
" new-style " issued to January 1st, 1897		317
" " " " during 1896		107
Total badges issued		1 436

Medals and Prizes.

The Norman Medal for the year terminating August 1st, 1895, was awarded to William Ham. Hall, M. Am. Soc. C. E,, for his paper on "The Santa Ana Canal of the Bear Valley Irrigation Company."

The Rowland Prize for the year terminating August 1st, 1895, was awarded to William Ryan Hill, M. Am. Soc. C. E., for his paper entitled "The Water-Works of Syracuse, N. Y."

Finances.

The reports of the Treasurer, Secretary, and of the Finance Committee, are appended.

By order of the Board of Direction.

CHAS. WARREN HUNT,
Secretary.

REPORT OF THE TREASURER.

In compliance with the provision of the Constitution, the Treasurer presents the following report for the year ending December 31st, 1896:

Balance on hand December 31st, 1895			$18 148 10
Receipts January 1st to December 31st, 1896			49 977 59
Payment of audited vouchers January 1st to December 31st, 1896		$56 669 81	
Balance on hand December 31st, 1896:			
In Union Trust Company	$3 212 86		
In Garfield National Bank	7 258 02		
In hands of the Secretary	985 00	11 455 88	
		$68 125 69	$68 125 69

The Society's securities are as follows:

	Par value.	Cost.	Market value. Bid.
One Chicago and North Western Railway Bond, 5%, coupon	$1 000	$1 035 00	$1 060 00
Seven Pennsylvania Railroad General Mortgage Bonds, 6%, registered	7 000	13 556 82	14 210 00*
Four Pennsylvania Railroad General Mortgage Bonds, 6%, coupon	4 000		
One Rio Grande Western Railway Bond, 4%, coupon	1 000	773 75	745 00
One Pittsburg and Western Railway Bond, 4%, coupon	1 000	818 75	740 00
One Elizabethtown, Lexington and Big Sandy Railroad Bond, 5%, coupon	1 000	1 000 00	990 00
One Certificate Croton Aqueduct Stock of the City of New York, 7%, registered	1 000	1 000 00	1,115 00
Ten Shares Stock Consolidated Gas Company of the City of New York	1 000	972 50	1 387 50
	$17 000	$19 156 82	$20 247 50

* Less accrued interest.

As predicted in last year's report, the surplus of the Society for the current year has materially increased; in fact, the net excess of receipts over disbursements, after taking proper account of payments on the new property and of dues paid in advance, it is nearly equal to the gain of both 1894 and 1895. Therefore, it may be proper to here state that, not only are the financial affairs of the Society on a most satisfactory basis, but that all indications are favorable to still further future development.

Very respectfully submitted,

JOHN THOMSON,

Treasurer.

JANUARY 13TH, 1897.

REPORT OF THE SECRETARY ACTING AS AUDITOR

To the Board of Direction of the

Gentlemen,—I have the honor to present the following statement beginning January 1st, 1896.

Receipts.

Balance on hand December 31st, 1895		$18 148 10
Entrance Fees..............................	$3 760 00	
Current Dues of 1896.........................	23 281 19	
Past Dues	1 043 00	
Advance Dues of 1897.........................	8 390 36	
Sales of Publications.........................	1 421 62	
Badges	654 35	
Certificates of Membership	163 50	
Advertisements..............................	1 863 30	
Interest on Securities and Cash in Trust Company........................	1 190 57	
Sales of Library Duplicates.........	1 50	
Binding *Transactions*.........................	652 92	
Legacy of McRee Swift.......................	1 000 00	
Miscellaneous...............................	48 51	
Rebate on Taxes	11 77	
		43 482 59
Subscriptions to New Society House..........		6 495 00
		$68 125 69

FOR THE YEAR ENDING DECEMBER 31st, 1896.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

of Receipts and Disbursements for the fiscal year of the Society,

DISBURSEMENTS.

Publications; net	$9 030 13	
Salaries	3 049 83	
		$12 079 96
Current Business, Salaries, Office Expenses, etc.		5 101 90
General Printing and Stationery		895 50
Postage		1 559 70
Library		1 374 81
Janitor		642 67
Badges		568 07
Contingencies		302 91
Gas		112 34
Water		17 55
Finance and Accounts		1 452 68
House Supplies and Furniture		272 71
Certificates of Membership		110 00
Fuel		128 25
Convention and Annual Meeting:		
Convention of 1896	$840 45	
Annual Meeting of 1896	561 34	
Annual Meeting of 1897	24 86	
		1 426 65
Insurance		126 80
Safe Deposit		16 00
Norman Medal, Rowland and Collingwood Prizes		127 16
Interest on Mortgage:		
5% on $11 500	$575 00	
For Appraising Premises, 127 East 23d Street	10 00	
		585 00
Taxes		492 20
Repairs and Betterments		92 48
Binding *Transactions*		210 60
		$27 695 94
New Society House:		
Purchase of Property, 218 and 220 West 57th Street	$17 000 00	
Recording Bond and Mortgage	12 50	
Examination of Title	378 24	
Interest on Mortgage	1 800 82	
Compensation to Competing Architects	1 976 73	
Vault Privilege	937 50	
Taxes	684 80	
For Excavating Lots	4 500 00	
C. L. W. Eidlitz' Fee as Architect	1 500 00	
For Circulars, Cuts, Printing, etc.	183 28	
		28 973 87
		$56 669 81
Balance in Garfield National Bank	$7 258 02	
" Trust Company	3 212 86	
" hands of Secretary	985 00	
		11 455 88
		$68 125 69

The compensation paid to each person in the service of the Society during the past year is stated below, and also the several accounts to which these payments have been distributed:

Charles Warren Hunt, Secretary and Librarian, January 1st to December 31st, 1896		$4 733 37
Charged to Publications	$1 497 00	
Current Business	2 308 37	
Finance and Accounts	350 00	
Convention and Annual Meeting	380 00	
Library	198 00	4 733 37

John Thomson, Treasurer, January 1st to December 31st, 1896.		
Charged to Finance and Accounts		$141 69

John M. Goodell, Assistant Secretary, January 1st to December 31st, 1896		$1 800 00
Charged to Publications	$1 250 00	
Finance and Accounts	375 00	
Current Business	165 00	
Library	10 00	1 800 00

Thomas B. Lee, Auditor and Chief Clerk, January 1st to February 1st, 1896		$150 00
Charged to Publications	$10 00	
Current Business	55 00	
Finance and Accounts	75 00	
Convention and Annual Meeting	10 00	150 00

Walter T. Brown, Accountant, March 12th to December 31st, 1896		$639 96
Charged to Finance and Accounts	$454 32	
Current Business	185 64	639 96

M. T. Jefferis, Assistant Librarian		$1 224 00
Charged to Publications	$193 33	
Current Business	18 00	
Finance and Accounts	6 67	
Library	1 006 00	1 224 00

B. J. Burke, Clerk.		
Charged to Current Business		$1 002 77

D. J. Mullen, Stenographer and Typewriter.
Charged to Current Business.......................... $780 00

M. A. Kent, Office Boy, January 1st to July 3d, 1896.
Charged to Current Business.......................... $112 67

Edgar Hawkes, Office Boy, June 29th to December 31st, 1896.
Charged to Current Business.......................... $118 93

Arthur C. Mander, Janitor, January 1st to September 4th, 1896.
Charged to Janitor.................................. $488 00

William Holm, Janitor, September 5th to December 31st, 1896.
Charged to Janitor.................................. $154 67

Stenographic Reporters..............................		$239 70
Richard W. Ryan.		
Charged to Convention and Annual Meeting...	$18 75	
Current Business..................	72 00	
Publications........................	99 50	
Adams, Curtis and Morrison, Charged to Current Business..............	6 25	
Ernest J. Mott, Charged to Convention and Annual Meeting.........	43 20	239 70

Francis C. Green, Temporary Attendant in Library.
Charged to Library.................................. $60

Total compensation paid.................. $11 645 76

DISTRIBUTION OF TOTAL COMPENSATION PAID.

Publications	$3 049 83
Current Business	4 824 63
Finance and Accounts	1 402 68
Convention and Annual Meeting	451 95
Library	1 274 00
Janitor	642 67
Total	$11 645 76

The funds of the Society are as follows:

FELLOWSHIP FUND:

Ninety-nine subscriptions to December 31st, 1896		$11 400 00
Premium and accumulated interest December 31st, 1896		1 388 28
Fund on hand December 31st, 1896		$12 788 28
Interest received during 1896 and expended for publications	$622 07	
Total amount in this Fund December 31st, 1896		$12 788 28

The present investment of this Fund is:

Nine Pennsylvania Railroad Bonds, cost	$11 111 82	
One Chicago and North Western Railroad Bond, cost	1,035 00	
Cash	641 46	
		$12 788 28

COMPOUNDING FUND:

Seven payments, at $325 00	$2 275 00
Nine payments, at $250 00	2 250 00
	$4 525 00

The present investment of this fund is:

One Pennsylvania Railroad General Mortgage Bond, 6%, cost	$1 222 50	
Ten shares Consolidated Gas Company of New York	972 50	
One Pittsburg and Western Railway Bond, 4%	818 75	
One Rio Grande and Western Railway Bond, 4%	773 75	
Cash	737 50	
		4 525 00
Carried forward		$17,313 28

Brought forward..............................	$17,313 28
NORMAN MEDAL FUND:	
One Certificate Croton Aqueduct Stock, New York City..	1 000 00
ROWLAND PRIZE FUND:	
One Pennsylvania General Mortgage Bond, 6%, cost	1 222 50
MCREE SWIFT FUND:	
Cash..	1 000 00
COLLINGWOOD PRIZE FUND:	
One First Mortgage Bond, 5%, Elizabethtown, Lexington and Big Sandy Railroad.................	1 000 00
Total..	$21 535 78

Respectfully submitted,

CHAS. WARREN HUNT,

Secretary.

REPORT OF THE FINANCE COMMITTEE.

The Committee has audited all bills which have been paid during the year, and has found that the amount of each has been charged to the proper account.

The Chairman of the Committee has examined the securities in the Safe Deposit Vault, and finds them to be as stated in the reports of the Treasurer and of the Secretary acting as Auditor.

In accordance with the provision of the Constitution, the accounts and financial books of the Society have been examined by an expert accountant and found correct.

The Committee refers to the report of the Board of Direction for matters in relation to expenditures connected with the New Society House. During the year the total current receipts amounted to \$42 482 59, or \$2 812 58 in excess of the collections during 1895, this excess being due in large measure to a more prompt advance payment of annual dues. The total current expenditures during the year amount to \$27 645 94, or \$3 308 95 less than in 1895.

JOSEPH M. KNAP, *Chairman*,
HORACE SEE,
WM. BARCLAY PARSONS,
F. S. CURTIS,
JOHN R. FREEMAN,
Committee on Finance.

ANNOUNCEMENTS.

HISTORICAL SKETCH OF THE SOCIETY.

Attention is called to the sketch of the history of the Society, written by the Secretary, which has been printed by order of the Board of Direction, and will be ready for delivery early in February.

Few members know much of the origin and growth of our organization and there is little accessible information concerning its early history. The meager official records have been amplified by material gathered by investigations in early technical literature and correspondence with members of the Society who took an active part in its establishment or in its reorganization. To the facts thus gathered has been added a summary of the more recent development and work of the Society, with a table of its yearly membership, and a diagram showing its growth as compared with that of other leading national societies.

The volume will be illustrated with a nearly complete set of portraits of officers of the Society, has been printed in the best man-

ner, and will be bound in full morocco and sold only on subscription at $10 per copy.

As stated in the report of the Board of Direction (see page 12), there will be a handsome profit to the Society at this price, which will be devoted entirely to the New Society House Fund, as the publication is intended to provide a way by which every person connected with the Society may make a small contribution to the new building and at the same time obtain a volume which it is believed will prove of great interest to him as an engineer.

Orders for this volume should be sent to the Secretary as early as possible as only copies enough to meet the demand will be bound.

MEETINGS.

Wednesday, February 3d, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by John Findley Wallace, M. Am. Soc. C. E., entitled "The Substitution of Electricity for Steam as a Motive Power for Suburban Traffic," will be presented. This paper was printed in *Proceedings* for December, 1896.

Wednesday, February 17th, 1897, at 20 o'clock, a regular meeting will be held at which a paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled "A Study in the Designing and Construction of Elevated Railroads, with Special Reference to the Northwestern Elevated Railroad and the Union Loop Elevated Railroad of Chicago, Ill.," will be presented. This paper is printed in this number of *Proceedings*.

Wednesday, March 3d, 1897, at 20 o'clock, a regular meeting will be held at which a paper by Julius Baier, M. Am. Soc. C. E., entitled "Wind Pressures in the St. Louis Tornado," will be presented. It is printed in this number of *Proceedings*.

DISCUSSIONS.

Discussion on the paper by Jules Breuchaud, Assoc. Am. Soc. C. E., entitled "The Underpinning of Heavy Buildings," which was presented at the meeting of January 6th, 1897, will be closed February 15th, 1897.

Discussion on the paper by John F. Wallace, M. Am. Soc. C. E., entitled "The Substitution of Electricity for Steam as a Motive Power for Suburban Traffic," which was presented at the meeting of February 3d, 1897, will be closed March 15th, 1897.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Name	Address	Grade	Date of Membership.
Lewis, Frederick Humphreville	406 Locust St., Philadelphia, Pa.		Jan. 6, 1897
Treadwell, Lee	Pencoyd, Pa.	J. A. M. M.	Nov. 5, 1890 Oct. 9, 1893 Dec. 2, 1896
Williamson, Sydney Bacon	U. S. Asst. Engr. Muscle Shoals Canal, Florence, Ala.	A. M. M.	Jan. 3, 1894 Dec. 2, 1896

ASSOCIATE MEMBERS.

Name	Address	Grade	Date of Membership.
Bergengren, Fritz Carl Anders Georg	Bolton House, Harrisburg, Pa.		Dec. 2, 1896
Constant, Frank Henry	Asst. Professor of Civil Engineering, Dept. of Structural Engineering, University of Minnesota, Minneapolis, Minn.		Dec. 2, 1896
Hill, Walter Arthur	Merced, Cal.		Sept. 2, 1896
Jenckes, Lawrence Bates	(Care of G. H. Hammond & Co.), Hammond, Ind.		Oct. 7, 1896
Reinholdt, Kenneth Oake Plummer	1314 Carnegie Bldg., Pittsburg, Pa.	J. A. M.	Feb. 6, 1894 Oct. 7, 1896

JUNIORS.

Name	Address	Grade	Date of Membership.
Knap, Edgar Day	256 West Seventy-third St., New York City		Dec. 1, 1896
Pruyn, Francis Lansing	84 Broadway, Brooklyn, N. Y.		Dec. 1, 1896
Ryder, Ely Morgan Talcott	10 Park St., New Haven, Conn.		Jan. 5, 1897
Strickler, Gratz Brown	3343 Prospect Ave., N. W., Washington, D. C.		Jan. 5, 1897
Wallace, Frederic Appleton	54 Hampshire St., Lawrence, Mass.		Sept. 1, 1896

CHANGES AND CORRECTIONS.

MEMBERS.

ADGATE, GEORGE ....Sioux City, Iowa.
AERTSEN, GUILLIAEM....................Gen. Mgr. Latrobe Steel Co., 1200 Girard Bldg., Philadelphia, Pa.
ATWATER, ALMON BYRON. ....Supt. Western Div., Grand Trunk Ry. System, Detroit, Mich.
BARLOW, JOHN QUINCY. ....Asst. Engr. Pioneer Electric Power Co., Ogden, Utah.
BATES, CHARLES JARVIS ....Consulting Engineer, Highwood, N. .
BAXTER, GEORGE S ....18 Wall St., New York City.
BEAHAN, WILLARD........................Leland Stanford University, Palo Alto, Cal.
BOGART, JAMES PETER ....Bogart & Sperry, Office, 82 Church St.; Residence, 684 Whitney Ave., New Haven, Conn.
BRECKENRIDGE, CABELL..................P. O. Box 263, Frankfort, Ky.
BRENDLINGER, PETER FRANKLIN..........810 North Forty-first St., Philadelphia, Pa.
BROWN, CHARLES IRWIN..................2815 Henrietta St., St. Louis, Mo.
CONNETT, ALBERT NEWMANN.............Thomson-Houston, 27 Rue de Londres, Paris, France.
CHURCH, BENJAMIN S.....................Cons. Engr.; Chf. Engr. Gold Creek Nevada Mining Co., Room 121, 66 Broadway, New York City.
DAVIS, CHESTER B.......................Cons. Engr., Rooms 603-604, 155 La Salle St., Chicago, Ill.
DOANE, EDWIN ALONZO....................Cons. Engr., Hapeville, Ga.
DOUGLAS, HENRY THOMPSON..............1 Carroll Hall, Baltimore and Calvert Sts., Baltimore, Md.
DUNLAP, DE CLERMONT...................Civil and Cons. Engr., Woman's Temple, 184 La Salle St., Chicago Ill.
ERLANDSEN, OSCAR.......................172 Centre St., New York City.
FAIRLEIGH, JAMES ANDREW...............P. O. Box 240, Harrisburg, Pa.
FILLEY, HIEL HAMILTON..................Chf. Engr. F. C. M. C. y P., Calle Encino 505, Ciudad de Mexico, Mexico.
FISHER, EDWIN AUGUSTUS................City Engineer, 16 Reynolds St., Rochester, N. Y.
FLAD, HENRY..............................3419 Laclede Ave., St. Louis, Mo.
FLAGG, JOSIAH FOSTER...................Thomasville, Ga.
GOULD, EDWARD SHERMAN................Yonkers, N. Y.
HAVEN, WILLIAM APPLETON...............Room 10, Erie R. R. Depot, Buffalo, N. Y.
HILLMAN, CHARLES LA FLETCHER.........Hope Villa, Baton Rouge, La.

HINCKLEY, JOHN FRANKLIN	Civil and Cons. Engr., 623 Security Bldg., St. Louis, Mo.
HISLOP, JOHN	Room 1, 1643 Champa St., Denver, Colo.
HOUSE, FRANCIS EDWIN	Chf. Engr., B. & P. R. R., Carnegie Bldg., Pittsburg, Pa.
HUNT, RANDELL	2209 Broderick St., San Francisco, Cal.
INGERSOLL, Jr., COLIN MACRAE	Asst. to the President N. Y., N. H. & H. R. R., Boston, Mass.
IVES, EDWARD BERNARD	Room 151, Bullitt Bldg., Philadelphia, Pa.
JACKMAN, HOWARD HILL	Asst. Engr. N. E. Lake Tunnel, Dept. Public Works, 112 W. Humboldt St., Sta. "D," Chicago, Ill.
JACKSON, JONES MUMFORD	Member of Firm, E. D. Smith & Co., Genl. Contractors, Schenectady, N. Y.
LANDRETH, WILLIAM BARKER	62 Port Watson St., Cortland, N. Y.
LINVILLE, JACOB HAYS	Box 4018, Sta. "B," Philadelphia, Pa.
LUCAS, DANIEL JONES	2d Asst. Engr., Penna. Ave. Subway and Tunnel, 502 North Eighteenth St., Philadelphia, Pa.
MASON, SAMPSON DOUGLAS	412 North Yakima Ave., Tacoma, Wash.
MASTEN, CORNELIUS STEWART	Hamilton, Ontario, Canada.
MITCHELL, HENRY	Box 1755, Boston, Mass.
MORSE, HENRY GRANT	Pres. The Harlan & Hollingsworth Co, Wilmington, Del.
McCARTY, RICHARD J.	Gen. Mgr. Augusta Ry. and Electric Co., 1624 Jefferson St., Kansas City, Mo.
OWENS, HENRY KINDER	Seattle, Wash.
PERKINS, CHARLES PENROSE	2005 De Lancey St., Philadelphia, Pa.
PEW, ARTHUR	Macon, Ga.
POYNOR, DAVID ASHLEY	Athens, Tex.
PURDY, CORYDON TYLER	160 Fifth Ave., New York City.
RICE, EDWARD CURTIS	3649 Pine St., St. Louis, Mo.
RICHARDS, HUGH TUDOR	1136 So. Hope St., Los Angeles, Cal.
ROBERTS, EVELYN PIERREPONT	Consulting Engineer, 22 William St., New York City.
ROBINSON, GEORGE HENRY	Mining Engineer, Walker Bank Bldg., Salt Lake City, Utah.
ROSENZWEIG, ALFRED	P. O. Box 653, City of Mexico, Mex.

ROSS, JAMES.................................Street Railway Chambers, Montreal, Canada.
ROWE, SAMUEL MCMATH.................. 87 74th St., Sta. "S," Chicago, Ill.
SCOVILL, E. TRACY.......................Secy. The Brown Hoisting and Conveying Co., cor. Hamilton and Belden Sts., Cleveland, Ohio.
SMITH, HENRY DE WITT..................Marshall, Tex.
TIMONOFF, VSEVOLOD EVGUENIEVITCH......Prof. Institute of Ways of Communication, Perspective Zabalkanski No. 9, St. Petersburg, Russia.
TURNER, NATHANIEL.......................100 Calle de Matamoras, Monterey, Mex.
VANCE, HART...............................Surveyor of Jefferson Co., Ky., County Court House, Louisville, Ky.
WATSON, WILLIAM..........................Baring Bros., London, Eng.

ASSOCIATE MEMBERS.

BAKER, ELISHA BROWN....................19½ N. Pennsylvania St., Indianapolis, Ind.
BOGGS, JOHN INNERARITY..................Care of L. A. Duffern, Ennis, Ellis Co., Tex.
BOWMAN, AUSTIN LORD.....................Room 717, Havemeyer Bldg., New York City.
CHESTER, JOHN NEEDELS....................Pittsburg Sales Mgr. for Henry R. Worthington, Ferguson Block, Pittsburg, Pa.
CHIBAS, EDUARDO JUSTO....................Darien Gold Mining Co., Panama, Rep. of Colombia.
CREUZBAUR, ROBERT WALTER..............Municipal Works and Mechanical Construction, Room 717, Havemeyer Bldg., New York City.
CUMMINGS, ROBERT AUGUSTUS............ 1825 Mount Vernon St., Philadelphia, Pa.
EHLE, BOYD...................................Tonawanda, N. Y.
HAYFORD, JOHN FILLMORE..................57 South Aurora St., Ithaca, N. Y.
HENDRICKS, VICTOR KING..................Engr. T. H. & I. R. R., Terre Haute, Ind.
HOUSTON, JOHN JAY LAFAYETTE...........6333 Yale Ave., Sta. "O," Chicago, Ill.
HOWARD, CHARLES POPE....................Deepwater, Fayette Co., West Va.
KUNZ, FREDERIC CHARLES..................Bridge and Const. Dept., Pencoyd Iron Works, Pencoyd, Pa.
MATHEWSON, ISAAC..........................Asst. Chf. Engr. Rio Grande, Sierra Madre and Pacific Ry., Ciudad Juarez, Chihuahua, Mexico, P. O. Box 381, El Paso, Tex.

McKenzie, Thomas.................... ....174 Weybosset St., Providence, R.I.
Saville, Caleb Mills....................Asst. Engr. Metropolitan Water Board, 3 Mt. Vernon St., Boston, Mass.
Stacpoole, Stephen Westropp...........Hotel de Diligencias, Orizaba, Estado de Vera Cruz, Mexico.

ASSOCIATES.

Chapman, Melville Douglas.............253 Broadway, New York City.
Johnston, John Parry....................826 Cuyahoga Bldg., Cleveland, Ohio.
Ransome, Ernest Leslie. ....757 Monadnock Block, Chicago, Ill.
Trautwine, Jr., John Cresson...... ....Chief of Bureau of Water (1321 Filbert St.), 257 South Fourth St., Philadelphia, Pa.

JUNIORS.

Adams, Julius Le Roy.......... ....155 Congress St., Brooklyn, N. Y.
Bell, Gilbert James......................Keithsburg, Ill.
Binion, Joshua............................Care of Mrs. Freed, 232 Madison St., New York City.
Boyd, James Churchill..................Hemore, Maine.
Braune, Gustave Maurice..............Care of Birmingham Bridge and Const. Co., 321 Chalifoux Bldg., Birmingham, Ala...............
Carter, Shirley...........................3 East Grace St., Richmond, Va.
Clarkson, Robert Cooke.................510 Drexel Bldg., Philadelphia, Pa.
Douglas, Frederick Luke................8 Adams St., Mt. Vernon, N. Y.
Eastwood, John Thompson..............308 North St., Portsmouth, Va.
Evans, Myron Edward ....429 East 51st St., New York City.
Folger, Edward Pell......................Box 84, care of Weigh Lock, Syracuse, N. Y.
Goddard, Loring Hapgood..............Supt. of Const. for Peters, Burns & Pretzinger, Architects, Dayton, Ohio; 380 West Eighth Ave., Columbus, Ohio.
Harris, Van Alen.........................91 Newton St., Marlboro, Mass.
Ives, Arthur Stanley.....................Asst. Engr. N. Y. and B. Bridge, 179 Washington St., Brooklyn, N. Y.
Kenney, Edward Fulbister.............Asst. Engr. Penna. R.R., Moore, Pa.
Kibbé, Augustus Sayre..................Engr. of Const. Wm. Wharton, Jr., & Co., Inc., 25th St. and Washington Ave., Philadelphia, Pa.; Box 227, Chester, Pa.
Kummer, Frederic Arnold..............Gen. Representative American Wood Preserving Co., 72 Trinity Place, New York City.

MOISSEIFF, LEON S.	Care of Wm. B. Parsons, 22 William St., New York City.
MOSES, JOHN CRANCH	Chief Draftsman, Boston Bridge Works, 70 Kilby St., Boston, Mass.
MCCORMICK, GEORGE KING	Cumberland Gap, Tenn.
PHILLIPS, FRED. CLINTON	Nashua Aqueduct, Clinton, Mass.
PHILLIPS, HOWARD CRATHORNE	Eddy, New Mexico.
POLAND, WILLIAM BABCOCK	275 North Delaware St., Indianapolis, Ind.
SIKES, GEORGE RICHARDS	871–875 Ellicott Square, Buffalo, N. Y.
STAIR, WILLIAM HOLLAND	Civil Eng. Q. M. Dept., Fort Hancock, Sandy Hook, N. J.
SMITH, CHARLES HORTON	City Engineer, 129 South St., Middletown, N. Y.
WATSON, THOMAS TAINTER	Manager Cispus Mining Co., Swofford, Lewis Co., Wash.
WILKERSON, THOMAS JEFFERSON	1418 Carnegie Bldg., Pittsburg, Pa.

FELLOW.

HARRISON, STEPHEN A.	71 Colby and Abbott Block, Milwaukee, Wis.

DEATH.

SMITH, ISAAC WILLIAMS	Elected Member October 1st, 1873; died January 1st, 1897.

RESIGNATIONS.

MEMBERS.

	Date of Resignation.
BARR, C. C.	December 31st, 1896
BOYD, CHAS. R.	December 31st, 1896
BRUEN, FRANK	December 31st, 1896
HILBERT, H. J.	December 31st, 1896
KING, F. P.	December 31st, 1896
SELLERS, WM.	December 31st, 1896
TOBIAS, JOB M.	December 31st, 1896

ASSOCIATE MEMBERS.

KINEALY, J. H.	December 31st, 1896
VON GEMMINGEN, S. O.	December 31st, 1896

JUNIORS.

BURDETT, CHAS. L.	December 31st, 1896
KNAPP, H. M.	December 31st, 1896
WEEKS, JR., ALFRED	December 31st, 1896

ADDITIONS TO

LIBRARY AND MUSEUM.

From C. W. Adams, Albany, N. Y.:
Annual Report of the State Engineer and Surveyor of the State of New York for the fiscal year ending September 30th, 1895.

From American Institute of Mining Engineers:
Action of Blast Furnace Gases upon Various Iron Ores; Copper Ores in the Permian of Texas; Faulting in Glacial Gravel; Laboratory Tests in Connection with the Extraction of Gold from Ores by the Cyanide Process; Magnetic Observations in Geological Mapping; Proceedings of the Seventy-first Meeting, Colorado, September, 1896; The Cyanide Process in the United States; The Magnetic Separation of Non-Magnetic Material; The Ore Shoots of Cripple Creek; The Phosphate Deposits of Arkansas; The Solution and Precipitation of the Cyanide of Gold; The Use of the Tremain Steam-Stamp with Amalgamation; Traces of Organic Remains from the Huronian Series at Iron Mountain Vein Walls.

From American Water-Works Association, New York, N. Y.:
Proceedings of the Sixteenth Annual Meeting, 1896.

From Board of Trustees of the Sanitary District of Chicago:
Proceedings December 2d, 8th, 9th, 10th, 16th, 23d and 30th.

From Alfred P. Boller, New York, N. Y.:
Central Bridge and 155th Street Viaduct, New York City. (Bound Photographs).

From Boston Transit Commission:
Second Annual Report for the year ending August 15th, 1896.

From Bennett H. Brough, London, Eng:
Mining at Great Depths.

From F. J. Cisneros, London, Eng.:
Navegacion por las Bocas de Ceniza.

From Stephen H. Emmens, New York, N. Y.:
The Argentaurum Papers.

From Mordecai T. Endicott, Washington, D. C.:
Hearings on House Bill 35 (On the Nicaragua Canal, before the Committee on Interstate and Foreign Commerce, House of Representatives)

From Factory Inspectors of New York, Albany, N. Y.
Tenth Annual Report for 1895.

From Percy C. Gilchrist, Middlesbrough, Eng.:
Paper on the Bertrand-Thiel Process.
Analyses of Metals and Steels taken from Charges made by the Bertrand-Thiel Process.

From John M. Goodell, Brooklyn, N. Y.;
Twenty-sixth Annual Catalogue of the Worcester Polytechnic Institute, 1896.

From Nicholas S. Hill, Jr., Baltimore, Md.:
Report of the Electrical Commission of Baltimore City, on a general subway system to be owned by the City of Baltimore.

From Institution of Civil Engineers of Ireland, Dublin, Ireland.
Transactions, Volume XXV.

From Institution of Engineers and Shipbuilders in Scotland, Glasgow, Scotland:
Transactions, Volume XXXIX.

From William Jackson, Boston, Mass.:
Report to the Selectmen of Brookline, on a Municipal Arc Light Plant.

From Rhys Jenkins, London, Eng.:
Power Locomotion on the Highway,

From O. H. Jewell Filter Co., Chicago, Ill.:
The Jewell Water Filter, Gravity and Pressure Systems.

From C. C. Martin, Brooklyn, N. Y.:
Report of the Trustees of the New York and Brooklyn Bridge for the year ending December 1st, 1896.

From Metropolitan Sewerage Commissioners of Massachusetts, Boston, Mass.:
Eighth Annual Report for the year ending September 30th, 1896.

From Michigan Mining School, Houghton, Mich.:
Catalogue, 1894-1896.

From Patent Office, London, Eng.:
Abridgment of Specifications of Patents for Inventions: Metals and Alloys; Artists' Instruments and Materials; Cooking and Kitchen Appliances; Cements and Like Compositions; Air and Gases; Ammunition, Torpedoes, Explosives and Pyrotechnics.
Reports of Patent, Design and Trade Mark Cases.

From Railroad Commissioners of Connecticut, Hartford, Conn.:
Forty-fourth Annual Report, September 30th, 1896.

From State Agricultural College, Fort Collins, Colo.:
Bulletin No. 33; See page of Return Waters from Irrigation.
Bulletin No. 35. Alfalfa.

From U. S. Department of Agriculture:
Yearbook for 1895.

From U. S. Department of Education:
Report of the Commissioner for the year 1894–95.

From U. S. Navy Department:
Information from Abroad; Notes on Naval Progress, October, 1896.
Notes on the Year's Naval Progress, July, 1896.

From U. S. War Department, Chief of Engineers:
Forty-one Reports of the Improvement of Certain Rivers and Harbors.
Nine Specifications for the Improvement of Certain Rivers and Harbors.

From George T. Walch, Madras, India:
The Engineering Works of the Godavari Delta Vol. I.

From George E. Waring, Jr., New York, N. Y.:
The Proper Disposal of Sewage

From E. A. Ziffer, Vienna, Austria:
Mittheilungen des Vereines für die Förderung des Local und Strassenbahnwesens, Vol. IV, 1896

Source Unknown:
Railway Management in Bengal.
Railway Construction in Bengal.
Navigation Canals in India.
Steam Launch Construction.

BOOK NOTICES.

STEEL: A MANUAL FOR STEEL USERS.

By William Metcalf. Cloth, 7½ x 5 ins., pp. 169. New York, John Wiley & Sons.

Mr. Metcalf explains in the preface his reasons for writing this manual. "In this little manual the effort is made * * * to give to all steel users a systematic, condensed statement of facts that could not be obtained otherwise, except by traveling through miles of literature, and possibly not then. There are no tables, and no exact data; such would be merely a re-compilation of work already done by abler minds."

The headings of the chapters show the nature of the subjects discussed, and are as follows:

General Description of Steel, and Methods of Manufacture; Applications and Uses of the Different Kinds of Steel; Alloy Steels and their Uses; Carbon; General Properties of Steel; Heating; Annealing; Hardening and Tempering; Effects of Grinding; Impurities and Their Effects; Theories of Hardening; Inspection; Specifications; Humbugs; Conclusions; Definitions of Shop Terms Used.

THE MANUFACTURE AND PROPERTIES OF STRUCTURAL STEEL.

By Harry Huse Campbell, B. S. Cloth, 9 x 6 ins., pp. 397. New York, The Scientific Publishing Company.

The first chapter in Mr. Campbell's book is on the "Errancy of Scientific Records," especially those pertaining to metallurgy, and discusses particularly the causes leading to the discrepancies in the results of chemical analysis. Then follow chapters on pig iron, wrought iron and steel, in which the general properties are discussed. The remainder of the text is devoted to the several phases under which steel presents itself to the manufacturer and engineer. High carbon steel, the acid-Bessemer process, the basic-Bessemer process, the open-hearth furnace in general and its basic and acid types, fuel, the cost of manufacture, segregation and homogeneity, annealing, the influence of hot working on steel, the history and shape of the test-piece, the influence of certain elements on the physical properties of steel, the classification of structural steel, welding, inspection and steel castings, are the subjects treated in the succeeding chapters. The book contains 138 tables, and closes with an index of 13 pages.

THE STORY OF AMERICAN COALS.

By William Jasper Nicolls, M. Am. Soc. C. E. Cloth, 9 x 6 ins., pp. 405, $3.50. Philadelphia, J. B. Lippincott Company.

In this volume Mr. Nicolls traces the history of coal from its origin, through the various stages of mining and transportation to its final use, confining his treatment entirely to American coals.

The first part of the book takes up 120 pages, and is devoted to the origin of the mineral. The contents of the several chapters are indicated by their titles: Theories, Geology, Early Mention, Historical, Geography, Area, Classification, Bituminous Area. The second part is on development, and, starting with a notice of the surface indications of a field, carries the subject through the various details of boring, drifting, air and gases, opening a mine, getting out the coal and hauling it to the surface, 94 pages being devoted to this section. The third part, of 88 pages, is a description of the various methods of shipping coal, and the fourth part, of 88 pages, treats of the consumption of coal in boilers, blast furnaces and gas works and allied subjects. An index of 15 pages concludes the volume.

1897. JANUARY. No 1..

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS:

A STUDY IN THE DESIGNING AND CONSTRUCTION OF ELEVATED RAILROADS, WITH SPECIAL REFERENCE TO THE NORTHWESTERN ELEVATED RAILROAD AND THE UNION LOOP ELEVATED RAILROAD OF CHICAGO, ILL.

By J. A. L. WADDELL, M. Am. Soc. C. E.

TO BE PRESENTED FEBRUARY 17TH, 1897.

The principal object of this paper is to bring out an exhaustive discussion on the subject of the designing and construction of elevated railroads. Hence, the author presents it to the American Society of Civil Engineers, with the earnest request that all the members of the Society who are interested in structural metalwork in general, and in the building of elevated railroads in particular, will take part in the discussion.

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

For some years the author had felt that the methods in vogue for constructing elevated railroads were radically wrong, so when he assumed the duties of Consulting Engineer to the Northwestern and Lake Street Elevated Railroads, in July, 1894, he began an elaborate investigation concerning the best way to design, manufacture, and build such structures. In reporting on some proposed plans for the Wabash Avenue Extension of the Lake Street line, which forms one side of the Union Elevated Loop Railway, he gave the following list of essentials of elevated railroad construction:

First. Loads.—The loads to be considered are these:

A. Live load.

B. Dead load.

C. Thrust of braked trains, or traction load.

D. Wind load, or in reality an assumed transverse load to provide for sway of trains.

E. Centrifugal loads on curves.

Second.—Designing.

F. Longitudinal girders should have sufficient sectional areas, and should be properly detailed.

G. A proper system of bracing between contiguous longitudinal girders should be provided.

H. There should be a proper connection of longitudinal girders to cross-girders.

I. There should be adequate means of transmitting the thrust of braked trains from longitudinal girders to columns without overstraining the cross-girders.

J. The cross-girders should be properly designed in respect to both sectional areas and details.

K. There should be a proper connection of cross-girders to columns to provide for transmission of both longitudinal and transverse horizontal loads.

L. The sections of the columns should be properly designed to provide sufficient strength to resist direct load, bending from longitudinal thrust, bending from transverse thrust, and, on curves, bending from centrifugal loads.

M. There should be a proper anchorage at the foot of each column to make the latter, as far as strength and rigidity are concerned, absolutely continuous with the pedestal.

N. There should be an adequate wooden floor, effectively attached to the metalwork of the superstructure.

O. The general construction of the entire structure should be as economical as practicable in respect to both quantities of materials and facility in erection, due respect being paid to the more important requirements affecting strength and rigidity.

P. The æsthetics of the design should be considered as much as possible without involving extravagant expenditure therefor.

This list of requirements will be referred to later on in commenting upon the details of existing American elevated railroads.

The immediate prosecution of the Lake Street Elevated work was a fortunate circumstance, as far as the investigations for the Northwestern Elevated were concerned, for it gave the author an opportunity to make certain experiments and researches which he might otherwise not have had, notably in the lines of bearing capacity of Chicago soil, details of structure occupying streets, and cold-pressed threads for bolts.

In these investigations the author has received valuable assistance from Charles V. Weston, Esq., who holds the position of Chief Engineer on the Northwestern Elevated, the Union Loop, and the Lake Street Elevated Railroads, and from Samuel M. Rowe, M. Am. Soc. C. E., who was retained temporarily to aid in the preliminary work.

The design of the Wabash Avenue Extension will be referred to later on; meanwhile the investigations for the Northwestern Elevated will be taken up in their consecutive order.

Before proceeding with these, however, it will be well to give a short description of the road. It starts as a double-track structure from the Wabash Avenue Extension of the Lake Street Elevated at the corner of Fifth Avenue and Lake Street, runs north across the Wells Street Bridge to Michigan Street; thence west to Franklin Street; thence north to Chicago Avenue, where it expands into a four-track structure (leaving the street and running into private property), whence it continues in a northerly and westerly direction to a point on Wilson Avenue between Evanston Avenue and the Chicago, Milwaukee and St. Paul Railway tracks, making the total length of line a little more than 6½ miles, of which all but 1 mile is four-track structure.

I.—Medium Steel *versus* Soft Steel.

At the outset it was necessary to determine whether it is more economical to use unreamed soft steel at a low intensity of working stress, or reamed medium steel at a higher intensity. This question was quickly settled in favor of the medium steel, which can be strained legitimately 10% higher than the soft steel, and costs practically the same per pound at the rolling mills. The ratio of weights of structure for designs in medium steel and soft steel is about as 93 is to 100, a saving of 7% in weight of metal in favor of the medium steel. Assuming the price of metal erected to be 3 cents per pound makes the saving in pound price 0.21 cent, while the cost of sub-punching and reaming varies from 0.1 to 0.2 cent per pound, according to the facilities of the bridge shop for doing such work. At present perhaps there is a slight difference in the pound prices erected of soft and medium steel in favor of the former, enough possibly to offset the net saving by reduced weight of the latter, so that, as far as the total cost is concerned, it is immaterial whether unreamed soft steel or reamed medium steel be adopted.

There is another point involved here, however, which is of far greater import than mere economy in cost of erected metal, viz., the proper matching of rivet holes in the component parts of built members. For several years the author has favored the sub-punching and reaming of all metal (although he has not always insisted thereon), not so much for the sake of the somewhat disputed benefit derived from removal of cracked metal by reaming, as for the greater certainty of obtaining properly matched rivet holes. His late investigations in this line, made by examining the shop work of the various bridge manufacturing companies of this country, both personally and through his assistant engineers and inspectors, confirm him to such an extent in this opinion that he is now prepared to make the following statement and to invite both criticism and denial thereof.

All structural metalwork, whether it be medium steel, soft steel, or even wrought iron, should be punched at least $\frac{1}{8}$ in. less than the diameter of the cold rivet and reamed to a diameter $\frac{1}{16}$ in. greater than same; and there is no bridge shop in existence which can turn out truly first-class work without sub-punching and reaming or drilling.

Even when the greatest care is taken in punching the metal of the component pieces of long members, many of the rivet holes will fail

to match by as much as $\frac{1}{8}$ in., and the author has within a year or two seen $\frac{3}{4}$-in. rivet holes elongated to $1\frac{1}{4}$ ins., merely to admit the rivets. Where several component pieces containing badly matched rivet holes are placed together and a tapered flexible reamer is used to enlarge the hole sufficiently to admit the rivet, the latter cannot possibly fill completely the irregular hole, and, therefore, if left in the piece, cannot act effectively. If condemned by the inspector on account of looseness, and then driven out, it will, on account of its crookedness, materially injure the metal about the hole and thus weaken the structure, perhaps doing more damage thereto than would the leaving in of the loose rivet.

The use of a tapered, flexibly connected reamer is all humbug, and is not true reaming at all, but merely a means of making it practicable to get the rivets through badly punched holes that assemble irregularly.

Real reaming can only be done with rigid reamers or drills that remain at all times at right angles to the surface reamed, and cut a cylindrical instead of a tapered hole. Such reamers as these are the only ones that ought to be employed on first-class metalwork, excepting, of course, in confined spaces where they cannot be used, and where the flexibly connected reamer must of necessity be employed.

The author knows well that these opinions are at variance with those of a majority of the manufacturers of structural steel, and it is on this account that he presents them so forcibly, hoping that those who differ with him will be induced to say so and to give their reasons for so doing. At the same time he would be pleased to have those manufacturers who agree with him endorse his opinions in the discussion.

That many manufacturers are opposed to sub-punching and reaming was shown very clearly at the lettings of the contracts for the Wabash Avenue Extension of the Lake Street Elevated, and for the Northwestern Elevated, one manufacturer going so far as to make a difference of one-third of 1 cent per pound between reamed and unreamed work.

At these lettings good evidence was also given confirming a statement of the author, viz.: "It has been hitherto the general opinion that almost any kind of a structure in respect to design, quality of material and workmanship will suffice for an elevated railroad." One

manufacturer remarked to the author in criticism of the plans and specifications submitted to bidders: "Why, your requirements in regard to details and workmanship are as rigid as if you were about to build a railroad bridge." The reply to this was, "Yes. I consider this structure to be just as important as any railroad bridge ever built."

And why should it not be just as important? Are not the live loads thereon more continuously applied, and is not the assumed maximum load very nearly reached many times per day? On these accounts, is it not even more important to make an elevated railroad absolutely perfect in every detail of design and construction than it is to so make a railroad bridge? The author would like to have this stand which he has taken criticised by those who disagree with him; for, if he be wrong, he ought to be corrected; while if he be right, the general practice of building elevated railroads ought to be modified fundamentally.

The author is by no means alone in his opinion that nearly all the elevated railroads of this country will, in the not very distant future, have to be replaced, and mainly on account of faulty detailing. Of what the faulty detailing consists will be dealt with further on.

At this point the author wishes to call attention to a very reprehensible practice, which these lettings exemplified quite forcibly, viz., attempting to overthrow the engineer's plans and specifications submitted for tendering. In the case of the Wabash Avenue Extension letting a most determined but unsuccessful effort was made to alter the author's plans, so when the specifications for the Northwestern Elevated were drawn, the following clause was inserted with the permission of the president of the company:

"All work herein outlined is to be done in strict accordance with the following specifications, the accompanying plans, and such instructions as may be given from time to time by the company's engineers. Bidders are hereby warned that they will be held strictly to the spirit of these specifications, and that it will be bad policy for any one to bid with the expectation that concessions will be made after the contract is closed, in order that the work may be cheapened; for while the company's engineers desire at all times to aid the contractors in every legitimate manner to do their work expeditiously and economically, at the same time they have given these plans and specifications the most thorough consideration, and know exactly what they need in respect to both design and quality of materials and workmanship. On this account bidders are respectfully requested not to complicate their tenders by putting in alternative bids based on proposed changes in

either plans or specifications; because such alternative bids will not be considered."

The result of the insertion of this clause was rather amusing, for attempts were made to overthrow not only the plans, but the specifications also. However, but little difficulty was encountered by the engineers in throwing out all alternative bids; and the contract was let to parties who were willing to tender without suggesting changes in the plans and specifications submitted to the bidders.

Another question that came up at these lettings was that of using acid or basic open-hearth steel. Preference was given to the former in the specifications, but such evidence was submitted to the engineers as to convince them that the basic product can be made as satisfactory as the acid, and at a trifle less cost; consequently, it was adopted. Since then, however, the reports of the company's inspectors indicate that the basic steel is not quite so uniform in quality as the acid; and that it may prove advisable in future specifications for basic medium steel to reduce the average ultimate stress limits from 64 000 lbs. to 61 000 lbs. per square inch.

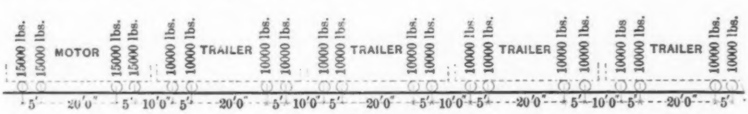


FIG. 1.

It appears to the author that the general adoption of basic open-hearth steel is fast tending to the employment of soft steel for bridges. As far as short and medium spans are concerned, this is all right, but it is the opposite for long spans, especially for very long ones, where the dead load is the ruling factor in proportioning the members. Perhaps in the near future some alloy of steel, such as nickel steel, can be made cheaply enough to warrant its use for very long span bridges.

A discussion on the effect of the adoption of basic steel upon the ultimate stress limit is herewith suggested.

II.—Weights and Dimensions of Motor Cars and Trailers.

After due deliberation it was decided to make both the motor cars and the trailers 40 ft. long out to out, and to carry each car on four axles, the weight of a loaded motor car being 60 000 lbs., and that of a loaded trailer 40 000 lbs. The distribution of this live load is shown in Fig. 1.

III.—The Best and Cheapest Kind of Portland Cement to Adopt, and the Best Proportions for Concrete Made with Same.

This investigation was made by Samuel M. Rowe, M. Am. Soc. C. E., who has promised to take part in the discussion. He certainly can contribute some valuable information to the general fund of professional knowledge concerning Portland cement.

As a result of these investigations the author has modified his standard specifications for cement so as to read thus:

"All cement used in the work shall be Portland cement of the very best quality obtainable, equal in every particular to the best brands of American manufacture. It shall be ground so fine that at least ninety-seven (97) per cent. in weight will pass a standard sieve of five thousand (5 000) meshes to the square inch, and so that at least ninety (90) per cent. will pass a standard sieve of ten thousand (10 000) meshes to the square inch.

"When moulded neat into briquettes and exposed three (3) hours, or until set, in air and the remainder of twenty-four (24) hours in water, it shall develop a tensile strength of from one hundred (100) to two hundred and fifty (250) pounds per square inch.

"When moulded neat into briquettes, and after exposure of one (1) day in air, and six (6) days in water, it shall develop a tensile strength of from two hundred and fifty (250) to five hundred (500) pounds per square inch; and after exposure of one (1) day in air, and twenty-seven (27) days in water, it shall develop a tensile strength of from four hundred (400) to six hundred (600) pounds per square inch.

"It shall be an eminently slow-setting cement, must develop its strength gradually, and must show no drop therein. When moulded into pats with thin edges, and either left on glass or not to set in water, said edges must show no signs of checking.

"Briquettes mixed in proportion (by weight) of one (1) part cement to three (3) parts sand, and kept one day in air and the remaining time in water, shall show a tensile strength of from one hundred (100) to one hundred and fifty (150) pounds per square inch after seven (7) days, and from one hundred and fifty (150) to two hundred and fifty (250) pounds per square inch after twenty-eight (28) days.

"In any case the cement adopted must be first approved by the Chief Engineer."

The proportions of Empire or Aalborg cements, which were the brands adopted for the Northwestern Elevated Railroad pedestals, used in making concrete, are:

One part by volume of cement.
Three parts by volume of sand.
Six parts by volume of graded broken stone.

Unless the stone be of several graded dimensions, so as to reduce the proportion of voids to a minimum, its proportion in the concrete should be reduced to five; for while these brands of cement will stand a three-to-one dose of sand, the resulting mortar will not fill completely all the voids in the stone at one, three and six, unless the grading of the stone be done very carefully, and unless the various sizes of stone be thoroughly mixed.

For concrete for bridge pier caissons, using these brands of cement, the author would recommend the following proportions:

One part by volume of cement.
Three parts by volume of sand.
Five parts by volume of broken stone.

In case, however, the concrete be deposited under water or in places where special strength and solidity are required, the proportions should be changed to one, two and four.

IV.—The Best and Cheapest Kind of Metal Paint to Adopt.

Mr. Rowe conducted this investigation also, but unfortunately was not able to complete his experiments. He has promised to give in his discussion his results as far as they go. It was decided to use for the Wabash Avenue Extension Eureka paint, and the National Paint Company's No. 31 for the Northwestern Elevated. In another structure, if the author could have his own way in respect to paint, he would give the metal a good coat of boiled linseed oil at the mills before it is exposed to the weather, one priming coat of Eureka paint at the shops, while the metalwork is still under shelter, and two coats of first-class iron oxide paint after erection.

V.—Prices of Timber F. O. B. Cars Chicago.

This investigation was made in order to determine what kind of timber to adopt, and whether it be advisable to specify all heart or a certain portion of sap, the result being that it was decided to use the best quality of long-leaf southern yellow pine entirely free from sap. This question of timber will be further treated in Section 12.

VI.—Best and Most Economical Span Lengths.

This question was investigated very exhaustively, considering every item of expense, including not only cost of metal in place, but also that of concrete, excavation, back-filling and pavement; also the pos-

sibility of expense for the moving of water pipes and other conduits. The investigation showed that for plate-girder construction through private property the economic span length is about 40 ft., while for construction in the street it varies from 47 to 50 ft., or even 3 or 4 ft. more in case of cross-girders spanning wide streets from curb to curb.

The theory of true economy in elevated railroad designing, as far as length of bays is concerned, is simply this: "The cost of the longitudinal girders should be, as nearly as may be, equal to the cost of the bents and their supporting pedestals, in case of doubt adopting the longer span."

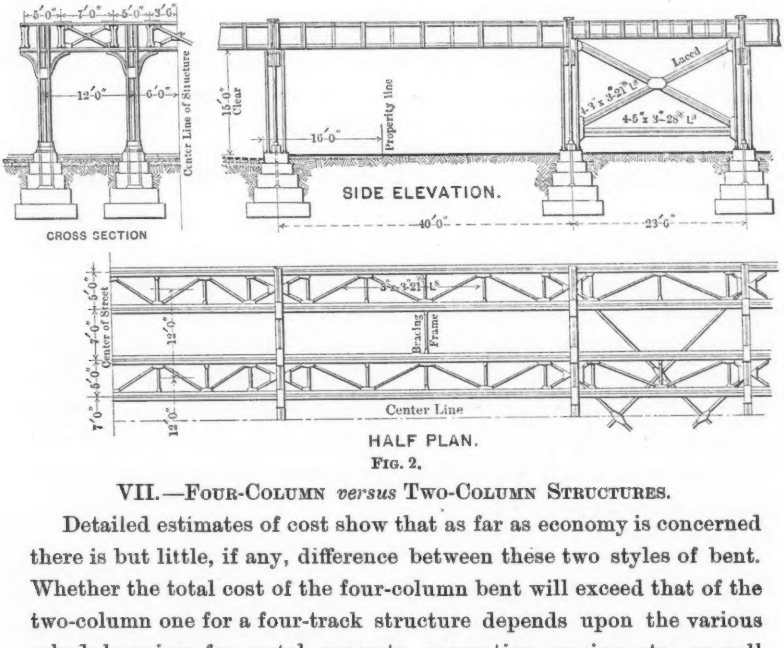


FIG. 2.

VII.—FOUR-COLUMN *versus* TWO-COLUMN STRUCTURES.

Detailed estimates of cost show that as far as economy is concerned there is but little, if any, difference between these two styles of bent. Whether the total cost of the four-column bent will exceed that of the two-column one for a four-track structure depends upon the various schedule prices for metal, concrete, excavation, paving, etc., as well as upon the character of the soil. As there is no great difference in the cost of these two types of structure, and as the four-column bent is decidedly the more rigid of the two, it was adopted wherever practicable. Fig. 2 gives a general elevation and plan showing the steelwork. Cantilevering an entire train load beyond the exterior column of a two-column bent is not conducive to rigidity, but this is the only method that will bring the cost as low as that of the four-column bent.

VIII.—Braced Towers *versus* Solitary Columns.

Where an elevated railroad occupies private property and crosses the streets by spanning from curb to curb, it is practicable to use

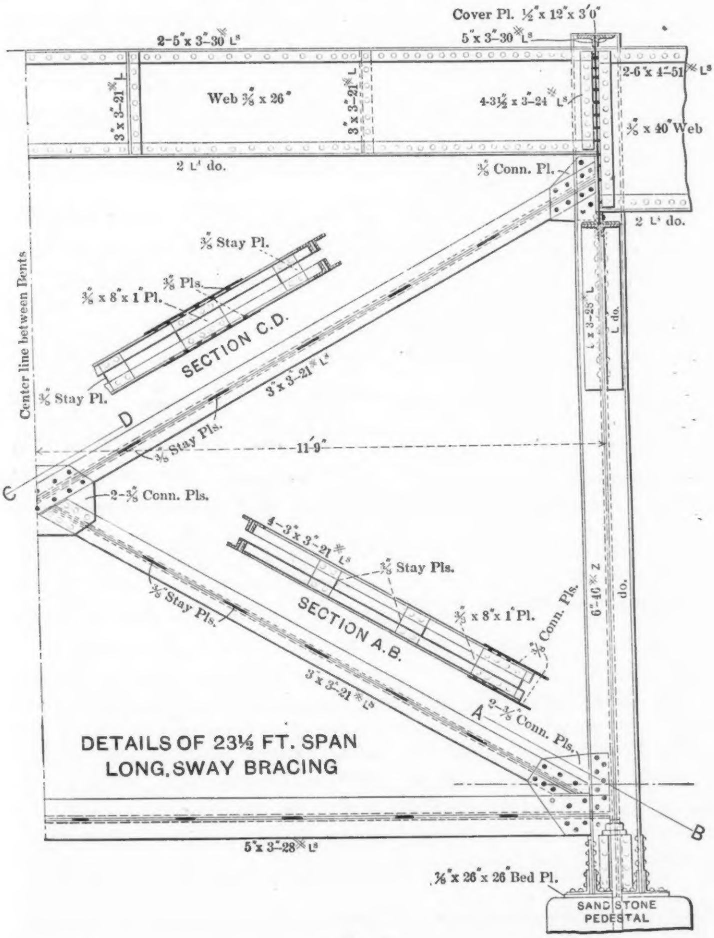


Fig. 3.

braced towers and thus stiffen the structure and check vibration; and, moreover, this arrangement is very economical.

For the Northwestern Elevated, upon which it is proposed to run trains at a speed of 40 miles per hour on the inner tracks between the

inter-track stations, which are situated about a mile apart, the consideration of the extra rigidity afforded by the braced towers is quite important. It was therefore decided to use both longitudinal and transverse sway bracing forming braced towers spaced about 150 ft. apart (or two towers per block), and to use the transverse sway bracing on all bents on curves, wherever practicable. Fig. 3 gives the details of the longitudinal sway bracing for a 23½-ft. span.

Two only of the three spaces between columns are to have transverse sway bracing, thus leaving a longitudinal passage-way for wagons at the center of the structure.

The saving in weight of metal per lineal foot of four-track structure on tangents by adopting braced towers instead of solitary columns was found to be about 140 lbs., or nearly 9% of the total weight.

Fig. 4.

IX.—The Best Weight and Dimensions of Track Rails.

After thorough investigation it was decided to adopt, as the best and most economical section, an 80-lb. rail, 5 ins. high, with vertical sides, and containing 45% of its metal in the head.

X.—Best Arrangement and Dimensions of the Wooden Floor.

The result of the investigation on this subject was, for longitudinal girders spaced 5 ft. centers, the adoption of 6 x 8-in. ties laid flat and spaced 14 ins. centers; 6 x 6-in. inner guards and 6 x 8-in. outer guards on edge, all guards being fastened by soft steel bolts with pressed threads, and connections to the metalwork being made by means of hook-bolts. Fig. 4 illustrates the track system.

XI.—Collection of Data of Various Kinds Concerning Elevated Railroads.

The results of this investigation, made by the author and his assistants by examining the principal elevated roads of the East and those then in operation in Chicago, as far as the designing of the metalwork is concerned, amount simply to the accumulation of a great mass of information exemplifying "how not to do it."

Such negative data are, of course, useful; but, if a properly designed and constructed road in operation could have been examined, the information accumulated would have proved much more valuable.

Much useful information, however, was obtained upon such matters as track, stations, signals, etc., by the examination of existing elevated railroads.

The author desires to acknowledge with many thanks his indebtedness to O. F. Nichols, M. Am. Soc. C. E., for valuable data, consisting principally of specifications, contracts and other printed matter relating to the Brooklyn elevated railroads.

XII.—Treated *versus* Untreated Timber for Tracks and Platforms.

After considerable investigation it was decided to preserve the timber by the vulcanizing process. The following extracts from the author's report to the company on this subject may be of interest.

"Unfortunately, the only vulcanizing works in this country are located in New York City; consequently, the freight rates on vulcanized timber delivered at Chicago are high, the average price for such timber as we need being about $32 per thousand delivered at site, while the untreated timber would cost only $18 per thousand. It will cost about $6 per thousand additional to put the timber in place.

"Vulcanized timber has been used on the New York Elevated Railroads for twelve years without showing any signs of material deterioration, and the chances are that it will last fully twenty-five years.

"Our investigations lead us to the conclusion that it costs about $1 per tie to replace ties in the track without interfering with the traffic, over and above the value of the tie itself; while for new work the cost of laying a tie is only 20 cents, making a difference of 80 cents.

"For the purpose of comparison let us take a mile of double track. The bill of timber therefor is as follows:

Ties....	9 052:	6 ins. x 8 ins. x	8 ft......	289 664 ft.
Guards.	920:	6 " x 8 " x	24 "......	88 320 "
Guards.	920:	8 " x 8 " x	24 "......	117 760 "
Planks..	5:	2 " x 8 " x	5 280 "......	35 200 "
Joists ..	1 508:	4 " x 8 " x	8 "......	32 171 "
				563 115 ft.
				Say 564 M.

"In order to be absolutely on the side of safety, let us assume the life of the vulcanized timber to be only fifteen years, or just twice that of the untreated timber, and that the excess of cost of replacing ties during traffic over that when there is no traffic is 60 cents instead of 80 cents per tie. The rate of compound interest assumed is 5 per cent. At the end of fifteen years, then, according to these assumptions, the floor in either case would have to be renewed, and the total costs for the fifteen years would be as follows:

For Vulcanized Timber.

564 M at $38..............................	$21 432 00
Compound interest on $21 432 for 15 years..	23 125 13
Total............................	$44 557 13

For Untreated Timber.

564 M at $24..............................	$13 536 00
564 M at $24..............................	13 536 00
9 052 ties at 60 cents......................	5 431 20
Compound interest on $13 536 for 15 years...	14 605 30
Compound interest on $18 967 for 7½ years..	8 383 50
Total............................	$55 492 00

"According to these figures the untreated timber is about 25% more expensive than the vulcanized timber, even upon assumptions that are manifestly unfavorable to the latter."

XIII.—Best and Cheapest Material for Pedestal Caps.

Estimates of cost were made on several types of pedestal caps, including castings like those used on the Metropolitan Elevated, Kettle River sandstone blocks and granitoid; and the last was adopted because it was considered both the cheapest and best. Experience with the finished pedestals has given the company's engineers no reason

to regret their decision concerning this matter. The granitoid covering for the concrete of the pedestals is 6 ins. thick, and is composed of one part of Portland cement and three parts of fine granite screenings, the top surface being made extremely smooth, to exact elevation, and perfectly level.

XIV.—Bearing Capacity of Chicago Soil.

Mr. Rowe made a number of experiments on the bearing capacity of Chicago soil, using an apparatus designed by the author, by which a load of pig iron was applied centrally to a square block of timber. As Mr. Rowe has promised to treat this subject in his discussion, no further details will be given here, except to state that the safe load in some places ran as low as 1 ton per square foot.

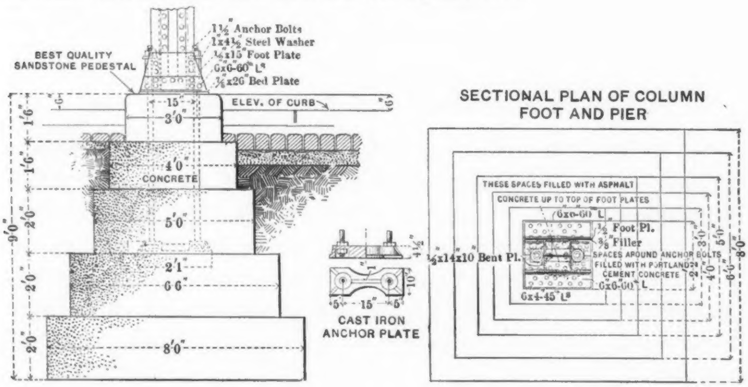


Fig. 5.

XV.—Best Style of Anchorage for Columns.

Where longitudinal sway bracing is employed, two anchor bolts per pedestal were used; but, where reliance was placed on the transverse strength of the column to resist the bending effects of longitudinal and transverse thrusts, four anchor bolts per pedestal were employed. All the anchor bolts of each pedestal were passed through a single anchor casting or spider embedded in the concrete, and set very carefully to exact line and level. The details of the foundation are shown in Fig. 5. The upper ends of the anchor bolts are enclosed loosely with a curved steel plate, long enough to contain an ample number of rivets for attaching to the column, and having

a square and smooth top to receive a heavy steel washer plate. As there are enough rivets connecting the curved plate to take care of both the direct and the secondary or induced stresses due to eccentricity, this entire pedestal detail is such as to make the column and the pedestal absolutely continuous, so that they act as a unit in resisting overturning; hence all calculations of strength of parts were made upon the assumption that the foot of the column is fixed.

A detail similar to this was employed by the author in 1891 when designing the columns and pedestals of the Sioux City train-shed; and, as far as he knows, this was the first time that a column-foot detail involving a truly fixed end for the column was ever used.

The ordinary method of running the anchor bolts through the horizontal foot-plate of the column near its edges or corners does not make a fixed-end column—far from it, as a few simple calculations will show.

XVI.—Plate Girders *versus* Open-Webbed Girders.

In designing these elevated railroads for Chicago, many estimates for both plate and open-webbed girders have been made, which demonstrate that there is practically no difference in the weight when both girders are properly designed. As the open-webbed girders cost a trifle more per pound to manufacture, there is no economy in their use; nevertheless they were adopted for all structures running longitudinally in the streets in order to comply with certain city ordinances.

The observance of these ordinances was sometimes carried to extremes, producing ridiculous combinations of solid and open web in the same girder, and an evident waste of material and labor. For this the engineers are not to blame, as it was not they who framed the ordinances.

XVII.—Crimping of Web-Stiffening Angles *versus* the Use of Filling Plates.

An investigation of this question was made by writing to a number of the leading bridge companies, and propounding to them this query: "If you had a lump sum contract for building a bridge would you find it more economical to use crimped angles for web stiffeners, or to adopt plain angles with fillers beneath them?" Some replies

favored crimping and some did not; but the majority, including most of the larger companies, considered crimping a little the more economical, especially for intermediate stiffeners; consequently on the

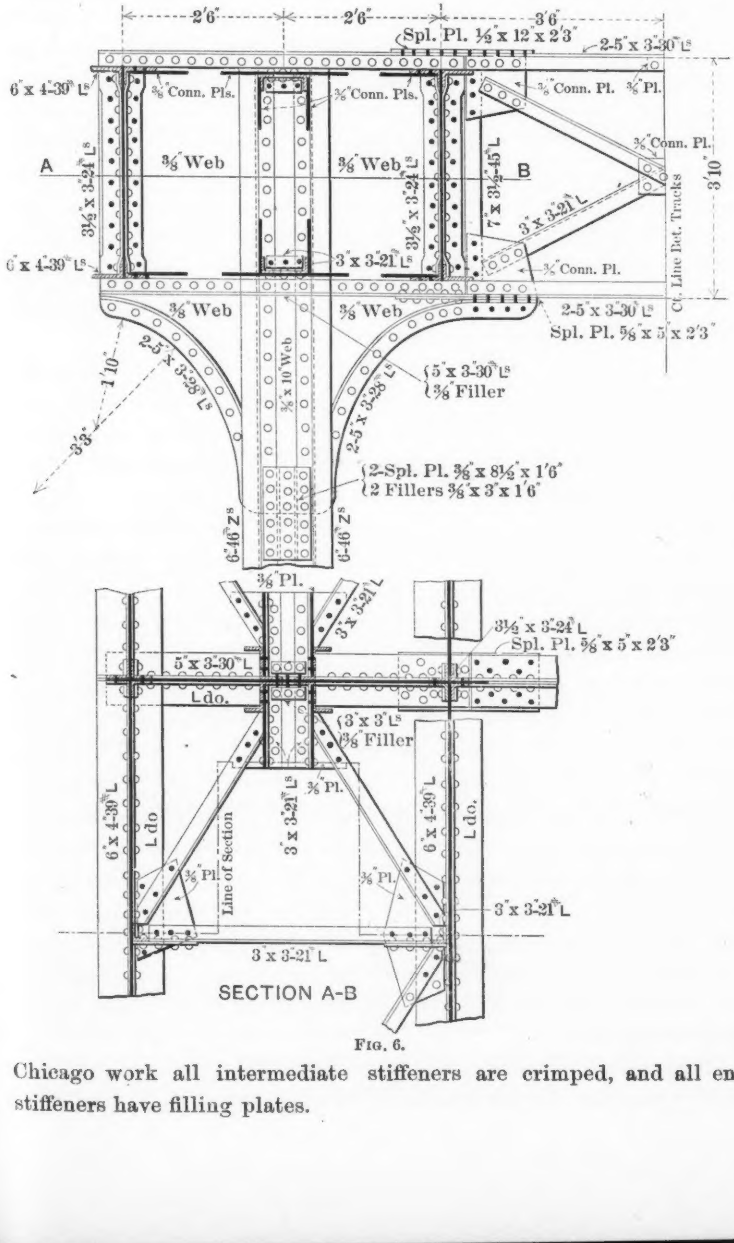


FIG. 6.

Chicago work all intermediate stiffeners are crimped, and all end stiffeners have filling plates.

XVIII.—Best Sections for Columns.

Investigation concerning strength, capacity to resist impact, facility of erection, economy of metal, etc., determined that the section for columns located in the street should be two 15-in. rolled channels with the flanges turned inward and a 15-in. rolled I-beam riveted between to act as a central web or diaphragm, the flanges of the channels being held in place by interior stay plates spaced about 3 ft. centers. In most cases the column feet pass below the pavement and are embedded in the concrete, to which, of course, they are bolted, but in some cases they rest on pedestals a little above the level of the sidewalk. The main object in turning the flanges inward is to enable the column better to resist impact from heavily loaded vehicles. Just above the pavement there is a curved casting filled with concrete and surrounding the column to act as a fender.

This column is a very satisfactory one after it is erected, although it gives some little difficulty in the shops and involves a little more field riveting than usual. One complaint made was that the top and bottom planes of flanges of I-beams are never exactly parallel to each other, so that some straightening was necessitated.

For columns located on private property or on sidewalks where the structure is transverse to the street, four Z-bars and a web plate were adopted as the most satisfactory section. At the top of the column a wide curved web plate and curved angles are used. This design makes a most satisfactory column, which goes through the shops readily, and which is well adapted for quick erection. It is true that it necessitated a special tool for cutting the webs to a circle, but after this was made, the manufacture was easy and comparatively inexpensive. The author would be pleased to see in the discussion by one of the engineers of the manufacturing companies a description of this special apparatus. These companies are the Union Bridge Company, of Athens, Pa., and the Elmira Bridge Company, of Elmira, N. Y., which together took the contract for the metalwork of the entire Northwestern Elevated and the Fifth Avenue side of the Union Loop. The Lake Street side of the Loop was built by the Phœnix Bridge Company of Phœnixville, Pa., and the other two sides are being built by the Pencoyd Iron Works of Pencoyd, Pa.

Figs. 6 and 7 illustrate features of the column construction, the latter figure also showing the details of an expansion joint.

XIX.—Best Style of Expansion Joint.

The designing of a perfectly satisfactory expansion joint is no simple problem ; consequently, it demanded considerable study, the result of which was the adoption of the pocket shown in Figs. 8 and 9 to receive the loose end of a longitudinal girder. The most important feature of

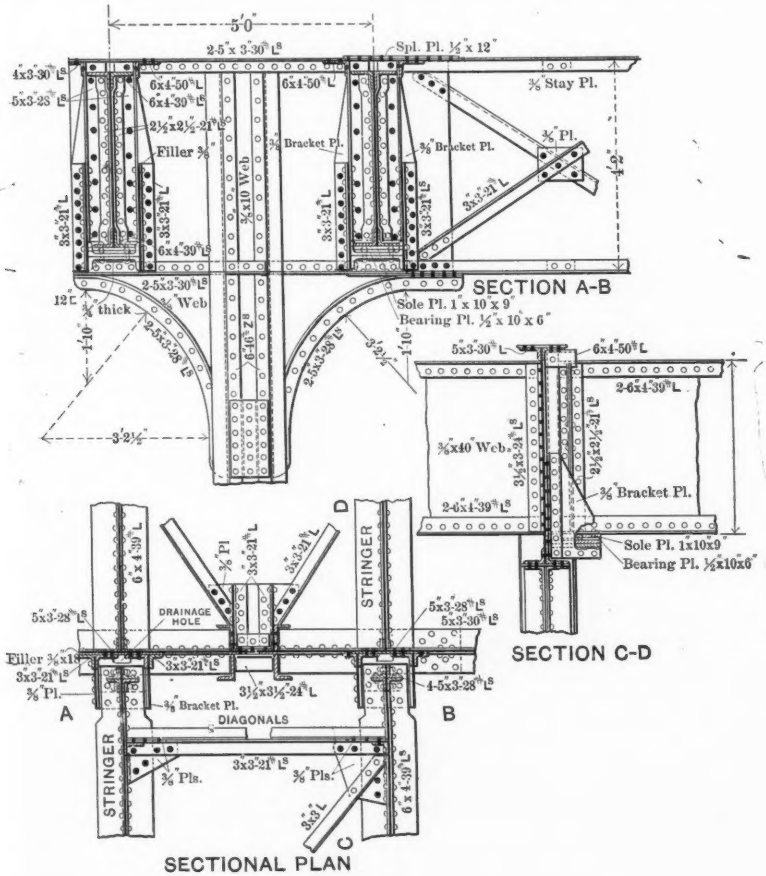


FIG. 7.

this design is that the center of pressure from the longitudinal girder is distant from the cross-girder about half the length of the pocket, which reduces the moment due to eccentricity upon the group of rivets connecting the pocket to the cross-girder, and prevents the

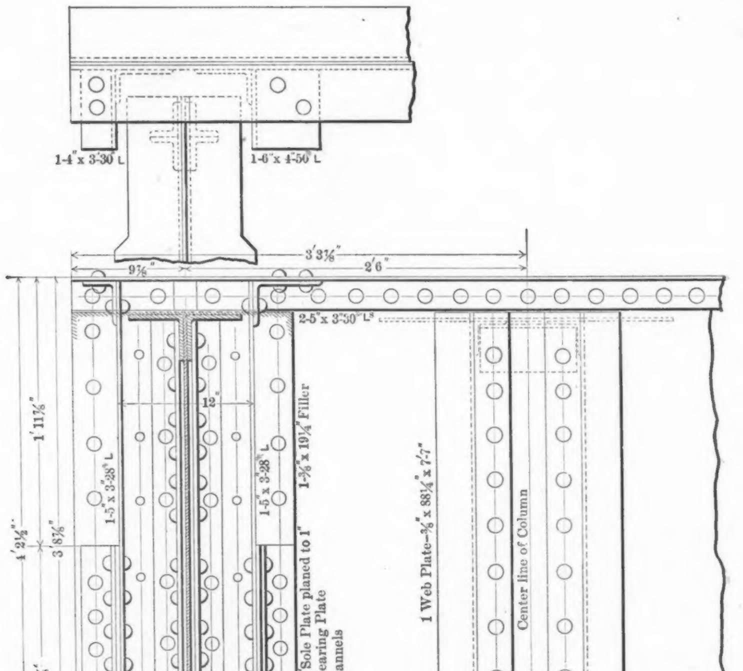
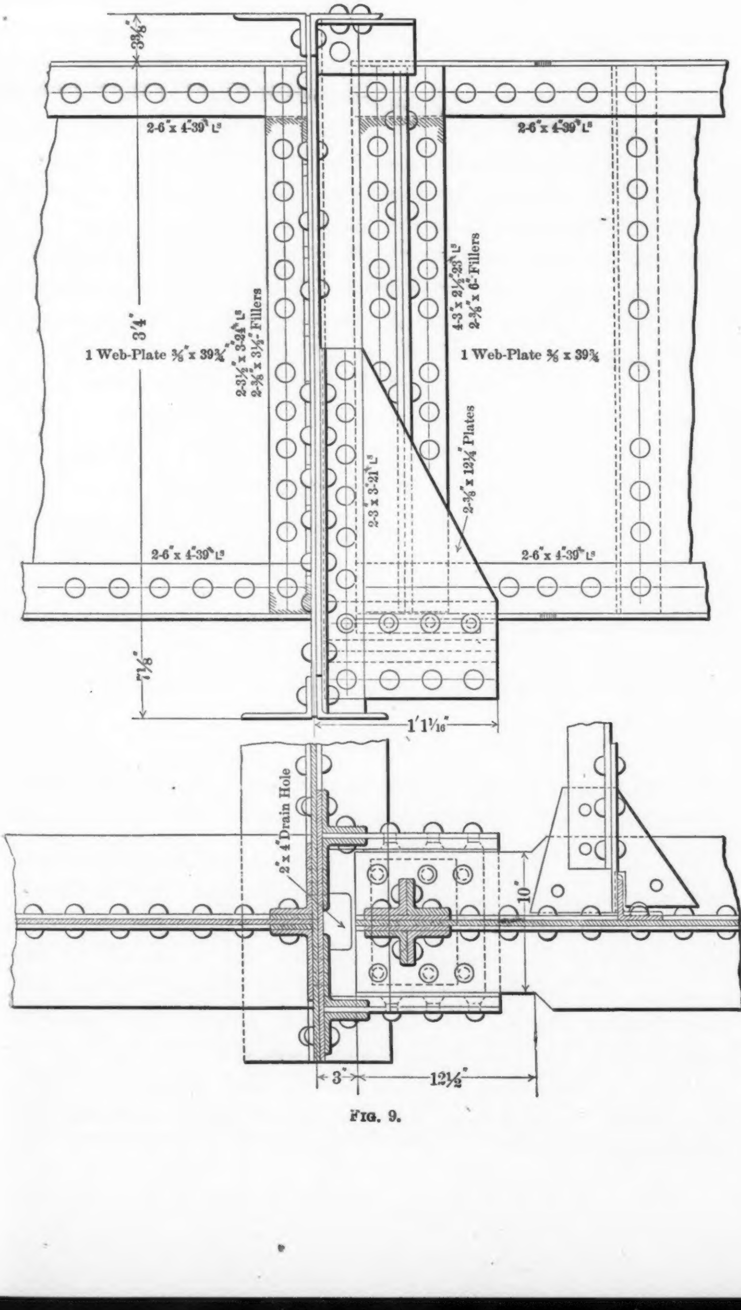

1-4" x 3-30" L
1-6" x 4-50" L
3' 3⅜"
9⅞"
2' 6"
2-5" x 3"-30" L^s
12"
1' 11⅞"
1-5" x 3"-28" L
1-5" x 3"-28" L
1-⅜" x 19¼" Filler
1 Web Plate—⅜" x 88¼" x 7'-7"
Center line of Column
1' 2½"
3' 8⅞"
2' 2⅝"
1-1½" x 9" x 10" Sole Plate planed to 1"
1-½" x 6" x 9" Bearing Plate
2 12-118.5" Channels
5⅞"
8½"
2-5" x 3"-30" L^s
2-5" x 3"-28" L^s

FIG. 8.



3⅜"
2-6" x 4"-39" L^s
2-6" x 4"-39" L^s
3'4"
1 Web-Plate ⅜" x 39¾"
2-3½" x 3"-24" L^s
2-⅜" x 3½" Fillers
4-3" x 2½"-23" L^s
2-⅜" x 6" Fillers
1 Web-Plate ⅜ x 39¾
2-⅜" x 12¼" Plates
2-3" x 3"-21" L^s
2-6" x 4"-39" L^s
2-6" x 4"-39" L^s
7⅛"
1'1⅟16"
2" x 4" Drain Hole
10"
3"
12½"

FIG. 9.

bearing of the longitudinal girder from coming on an edge of metal as would be the case were not the center of pressure thrown towards the cross-girder by the small base plate. Again, the number of rivets connecting the pocket to the cross-girder is ample for both the direct shear and the secondary stresses due to the moment caused by the eccentric bearing. The longitudinal girder fits tightly laterally in the pocket, and its top is held between angle clips riveted to the cross-girder. Thus the expansion ends of the longitudinal girders are held laterally to the cross-girders just about as rigidly as are the riveted fixed ends.

The detailing of the entire expansion end is so arranged that all parts of the metalwork are accessible to the brush for painting, although extra care will have to be used by the painter on this portion of the structure, in order to make sure that no portion of the surface is unprotected.

XX.—Style of Bracing on Curves.

The extra bracing on curves is composed of two lower lateral systems, each pertaining to two tracks, and consisting of a double system of cancellation, the diagonals being formed of two 4 x 3-in. angles riveted together and to the lower flanges of the longitudinal girders where they cross the same. The columns on curves are made larger and stronger than those on tangents, in order to resist properly the centrifugal loads.

XXI.—Proper Limit of Length of Structure between Expansion Joints.

This question involves the effects of changes of temperature, more especially in producing bending on the columns. The latter were figured for deflection with due regard to the fixedness of their ends, which increases the extreme fiber stresses due to changes of temperature. The investigation showed that 150 ft. should be the ordinary limiting distance between expansion points. On almost the entire lines of the Northwestern and Loop, this limit was observed; but in two or three cases, owing to peculiar local conditions, it had to be exceeded. In these cases, however, the columns most affected were strengthened.

XXII.—Track-Bolt Nuts Above *versus* Track-Bolt Nuts Below.

Each method has both good and bad features. With nuts below, the hole through the wood can readily be protected from the entrance of water, but the nuts may work off the bolts without notice being taken of the fact by the track-walker. With nuts above, any loosening of the bolts would be seen at once, but a water-tight joint is hard to make. The latter arrangement, after much discussion, was adopted, and cup-shaped washers let into the wood were employed. A liberal use of paint in these cups will probably seal them against percolation of water, but their insertion in the wood seems like an invitation for rot. An important advantage in using these cups is that there are no projecting nuts above the wood to trip anyone walking over the track.

XXIII.—Superelevation on Curves.

It was decided not to attempt to obtain this by elevating or depressing the longitudinal girders, or by using wooden shims on outer girders, but to employ wedge-shaped ties. Three bevels only are used on the line, viz., 1, 2 and 3 ins. in 5 ft. Such bevels, it is true, will not afford the theoretical superelevation required for the maximum speed on sharp curves; but it was considered that this maximum speed could not be maintained on sharp curves, hence the compromise between theory and practice. Experience in operation alone will tell whether the decision of the company's engineers in this matter is correct.

XXIV.—Best Styles of Stations.

For stations on the company's private property it was decided to adopt a single brick house to accommodate the entering passengers for all four tracks, the exit passengers leaving the platforms by special exit stairways leading to or near the street, each of said stairways being provided at its foot with a turnstile prohibiting entrance but permitting exit. This arrangement dispenses with several platform employees and prevents the station house and stairways from obstruction by passengers moving in opposite directions.

At first it was intended to run the exit stairways at right angles to the line and land on the sidewalks of the cross-streets, as shown in Fig. 10, but it was found afterwards that this method would in some cases involve the payment of unduly high damages to property-owners,

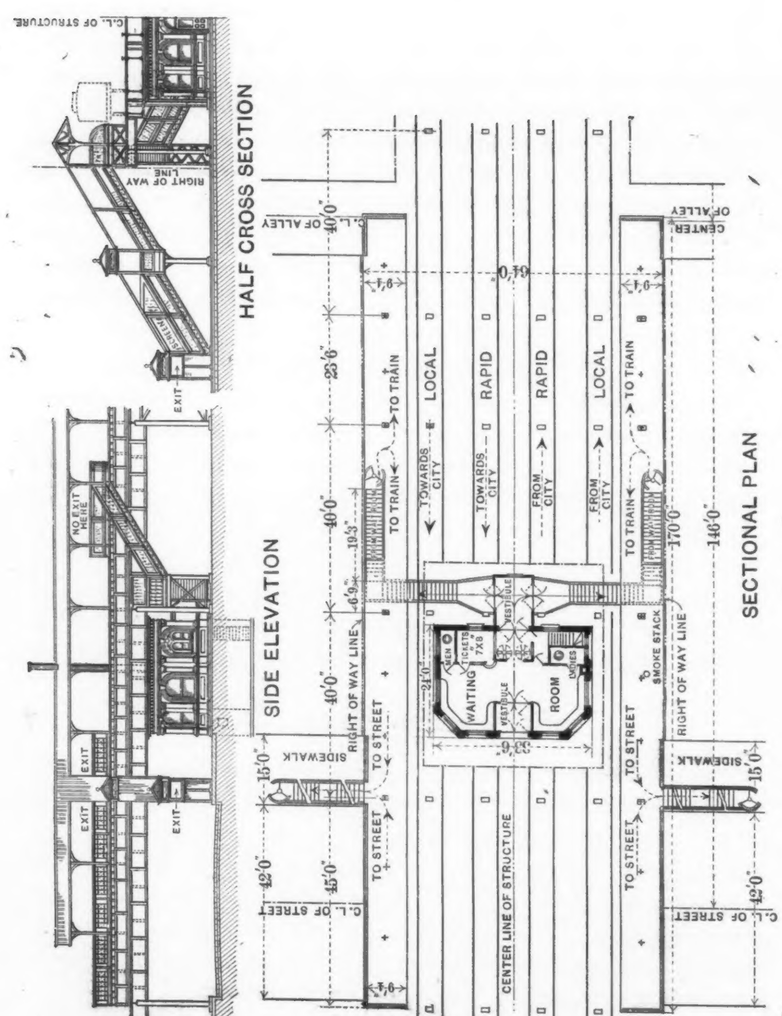

HALF CROSS SECTION
C.L. OF STRUCTURE
RIGHT OF WAY LINE
SIDE ELEVATION
NO EXIT HERE
EXIT
EXIT
EXIT
EXIT
SECTIONAL PLAN
C.L. OF ALLEY
CENTER OF ALLEY
C.L. OF STREET
C.L. OF STREET
SIDEWALK
SIDEWALK
TO STREET
TO STREET
TO STREET
TO STREET
TO TRAIN
TO TRAIN
TO TRAIN
TO TRAIN
TOWARDS CITY
TOWARDS CITY
FROM CITY
FROM CITY
LOCAL
RAPID
RAPID
LOCAL
CENTER LINE OF STRUCTURE
RIGHT OF WAY LINE
RIGHT OF WAY LINE
SMOKE STACK
WAITING
ROOM
TICKETS 7X8
MEN
LADIES
VESTIBULE
VESTIBULE
40'0"
23'6"
40'0"
19'3"
6'9"
40'0"
15'0"
42'0"
45'0"
64'0"
33'6"
24'0"
170'0"
146'0"
15'0"
42'0"

Fig. 10.

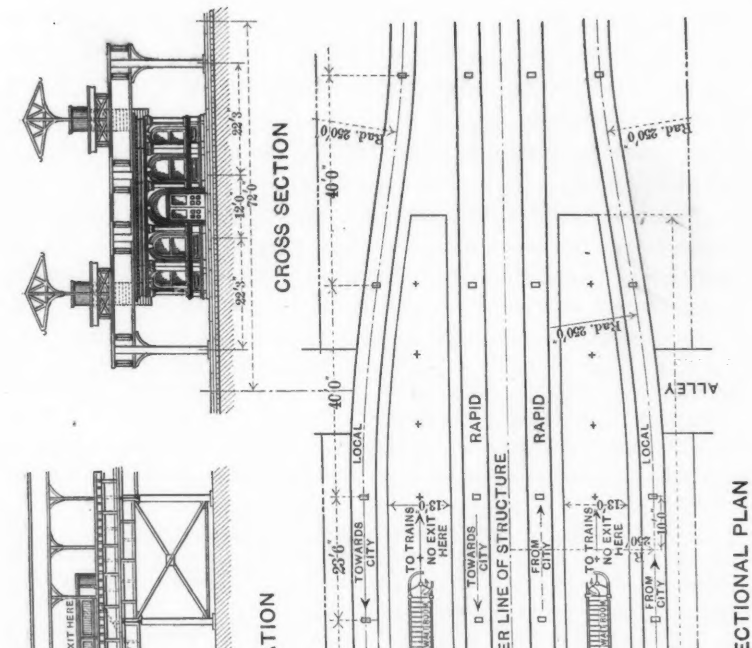

CROSS SECTION
SIDE ELEVATION
SECTIONAL PLAN
NO EXIT HERE
EXIT
RIGHT OF WAY LINE
CENTER LINE OF STRUCTURE
LOCAL
RAPID
TOWARDS CITY
FROM CITY
TO TRAINS
WAITING ROOM
TICKETS
MEN
LADIES
ALLEY
STREET
SIDEWALK

FIG. 11.

so it was decided to confine these stairways entirely to the company's property, as in Fig. 11. From the operating point of view the first design is the better one in that it does not cut up the already somewhat narrow platforms with apertures for exit, as does the design adopted. However, the pressure of the financial department was too strong for the engineers; consequently, the proposed change was adopted.

The following extracts from the specifications for stations on the Northwestern Elevated, together with occasional reference to Figs. 10 and 11, will give a fairly clear idea of what these stations will be like when completed.

"There are two slightly different styles of stations on the line, viz.: 'Interior Track Stations' and 'Exterior Track Stations,' the former being placed at intervals of about one mile, and the latter at intervals of about a quarter of a mile.

"The essential points of difference in the two styles of stations are in the platforms and in the vestibule and stairways leading thereto.

"In the Exterior Track Stations the platforms are outside of the tracks, while in the Interior Track Stations they are between the exterior tracks and those adjacent thereto, the exterior tracks being spread so as to pass around the platforms.

"There will be but one house to each station, passengers entering the same from the street, but not passing through it when leaving the line, as special exit stairways leading to the street are provided.

"The houses are to be built as follows: The basement walls are to be composed of rubble, resting on dimension stone footings; the main walls are to be of common brick, faced with pressed brick and terra cotta trimmings; the roof is to be a composition gravel roof; the floors are to be of white oak, resting on common yellow pine flooring over yellow pine joists; and the finish is to be of antique oak. The houses are to be lighted by both electricity and gas, and are to be heated by hot water.

"The ticket office is located to one side of the rear vestibule, which latter leads to the entrance stairways, which in turn lead to the platforms.

"These platforms are to be constructed of transverse and longitudinal timbers with a two-inch (2") vertical-grain yellow pine flooring on top. They are to be sheltered by canopies of corrugated iron supported by steel frame construction.

"Around all stairway openings, along the outside of exterior platforms, and at ends of all platforms are to be gas-pipe hand-railings paneled with grillework screens."

XXV.—Best Method of Heating Stations.

After considerable deliberation and discussion it was decided to heat all stations with hot water. This is undoubtedly the most satisfactory method for houses on the ground; but for the Loop stations and those of the Northwestern which are supported by the metal-work, the author would have preferred heating by gas so as to avoid the carrying to and fro of coal and ashes, with the unavoidable accompanying dirt and trouble. The use of gas, though, would have been more expensive than that of coal.

XXVI.—Relative Costs of Double-Track Structure with Columns in the Street and with Columns Just Inside of Curb Lines.

This question was investigated so as to determine whether in certain cases it would be worth while to strive for permission to put the columns in the street. As will be seen in the table given under Section XXVIII, the cost of structure per mile of double track was estimated to be $267 760 with columns inside of curbs, and $240 537 for columns in street, making a difference of $27 223 per mile of double track, or a relative difference of between 11 and 12 per cent.

XXVII.—Pressed-Thread Bolts *versus* Cut-Thread Bolts.

As the manufacture of pressed-thread bolts is a patented process, the author first obtained from the patentees a guaranteed pound price for their bolts delivered f. o. b. cars Chicago, at the same time getting corresponding prices for both upset and plain bolts with cut threads. He then had his metal inspectors test to destruction several specimens of pressed-thread bolts so as to determine their strength in comparison with cut-thread bolts.

As the difference in the pound prices was small, and as the strength of the pressed-thread bolts is fully 50% greater than that of the cut-thread bolts, the comparison resulted greatly in favor of the former, so they were adopted for all the anchor bolts and track bolts on both lines of road. The author feels that he cannot speak too highly of these pressed-thread bolts, for the results of the tests were surprising. When it is considered that the cold-pressing process reduces the effective diameter of the soft steel rod at the root of the thread, and in fact increases it but little at the edges, it might be imagined that when the bolt is tested to destruction, it would break in the

threaded portion. Such, however, is not the case, for all the specimens broke in the body of the rod, and, strange to say, the threads were so little injured that the nuts could be turned readily over the whole length of same.

XXVIII.—Studies Involving a Number of Designs for Different Styles of Structure.

The investigations included under this heading are the most elaborate of all those made. They involved careful designs and estimates of cost of the following types of structure, all of which are shown in cross-section in Figs. 12 to 24 inclusive.

Design 1. Four-track structure with longitudinal bracing, supported by four Z-bar columns, the cantilevers and columns being made in one piece in the shops.

Design 2. Similar to Design 1, except that the cross-girders are riveted to the columns in the field, and the brackets are omitted.

Design 3. Four-track, two-column structure, with longitudinal bracing.

Design 4. Four-track, four-column structure, without longitudinal bracing.

Design 5. Four-track, two-column structure, without longitudinal bracing.

Design 6. Double-track, two-column structure, with longitudinal bracing, similar to Design 1.

Design 7. Double-track, two-column structure, with longitudinal bracing, similar to Design 2.

Design 8. Double-track, two-column structure, with longitudinal bracing, the columns being spaced 17 ft. centers transversely to the structure.

Design 9. Double-track, two-column structure, without longitudinal bracing, similar in construction to Design 4.

Design 10. Four-track, four-column structure, without longitudinal bracing, the columns being flared out at the top and extending only to the plane of the bottoms of stringers, and the column section being composed of two 15-in. I-beams.

Design 11. Four-track, four-column structure, similar to Design 10, except that channels are used instead of I-beams in the columns.

Design 12. Double-track, two-column structure, without longitudinal bracing, for the alternative route along Fifth Avenue and Franklin Street, the columns being placed on the curbs.

Design 13. Double-track, two-column structure, without longitudinal bracing, also for the alternative route along the streets, the columns in this case being placed in the roadway.

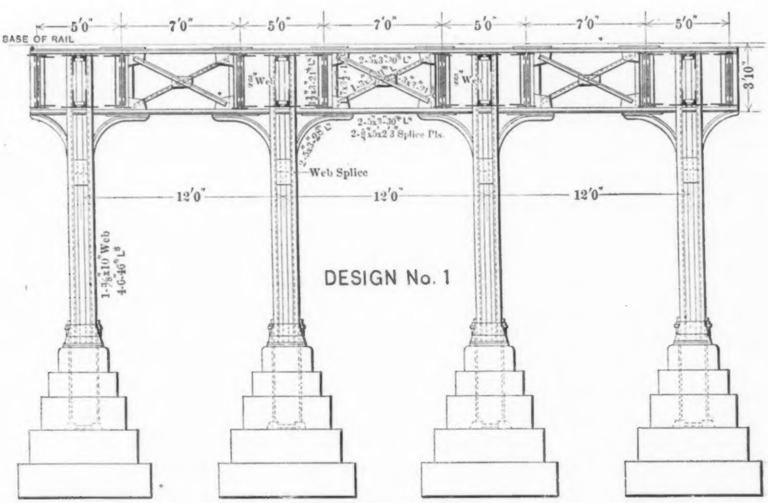


FIG. 12.

The following is an almost verbatim extract from the author's report, all references to drawings being omitted.

In explaining and discussing each of these designs, the following questions in the order here given will be considered: First, general description; second, strength; third, rigidity; fourth, economy; fifth, æsthetics; sixth, uniformity of construction; seventh, facility of manufacture and erection.

In making these various calculations there has been assumed a typical block 292 ft. long, simply for purposes of comparison. This block, however, is of about the average length of the blocks through which the line will pass.

Design 1, Fig. 12.

Design 1 is a four-track structure which is supported by four Z-bar columns.

General Description.—Each track is carried by a column which is located directly beneath its central line. The stringers are spaced 5 ft. apart, and are, therefore, almost directly beneath the rails. They are carried by short cantilevers, one on each side of the column. The web of these two cantilevers and that of the top of the Z-bar column are all in one piece, this web being carried through the top of the column. The top flange of the cantilevers is also continuous over the top of the column, and its web is carried far enough down the column to form a good bracket on each side.

The spans are all to be 40 ft. in length, excepting those over the street, which are 45 ft., and those having longitudinal bracing, which are 23 ft. 6 ins. There will be two such braced spans to each 292-ft. block, and a correspondingly greater number for blocks of greater length. This longitudinal bracing is designed to take up the entire horizontal thrust due to braked trains or to traction, the intermediate columns being designed to carry only the direct load and transverse thrust from wind load.

The stringers or longitudinal girders are plate girders, riveted up solidly to the cantilever brackets, except at the expansion ends. The expansion joints are spaced about 150 ft. apart, and will be similar in design to those used on the Wabash Avenue Extension of the Lake Street Elevated Railroad. The longitudinal thrust due to expansion and contraction of the stringers is carried to the column in each bent by short struts, but the longitudinal thrust due to braked trains is carried by the stringers directly to the longitudinal bracing.

On curves, where permissible, a system of vertical sway bracing will be used, and, where it cannot be employed, the columns will be made strong enough to transmit the transverse thrust to the pedestals.

These pedestals are to be made of concrete, covered with granitoid.

Strength.—Every portion of this structure has been made amply strong to carry the greatest stresses and loads which can come upon it. It would be difficult to make stronger or more efficient columns and cantilevers than the ones used throughout this design; for these columns, cantilevers and brackets are made in one piece in the shops, and there is not a weak point in them.

The bracing towers, if they may be so termed, are well braced, both longitudinally and transversely in vertical planes, and horizontally at the top, and take care most effectively of the total longitudinal thrust.

Rigidity.—The stringers are thoroughly braced together so as to prevent as much as possible all transverse vibration, and this bracing, together with the longitudinal sway bracing in the towers, prevents any undue longitudinal vibration. As the columns are placed directly

beneath the centers of the tracks, there is no possibility of unequal deflection in the transverse girders and cantilevers, such as might occur if the columns were not so placed. All columns are anchored to the pedestals by long anchor bolts which extend well into the concrete and make the column and pedestal act as one piece. Upon the whole this design is so constructed as to make it as rigid a structure as can be obtained.

Economy.—While this structure has been made thoroughly first class in every respect, no material has been wasted in so doing. The spans have been made of the most economical lengths; the spacing of columns transversely to the structure, the sections of columns used, the style of cantilever and the stringer bracing are all examples of true economy of design, but probably the feature that saves more metal

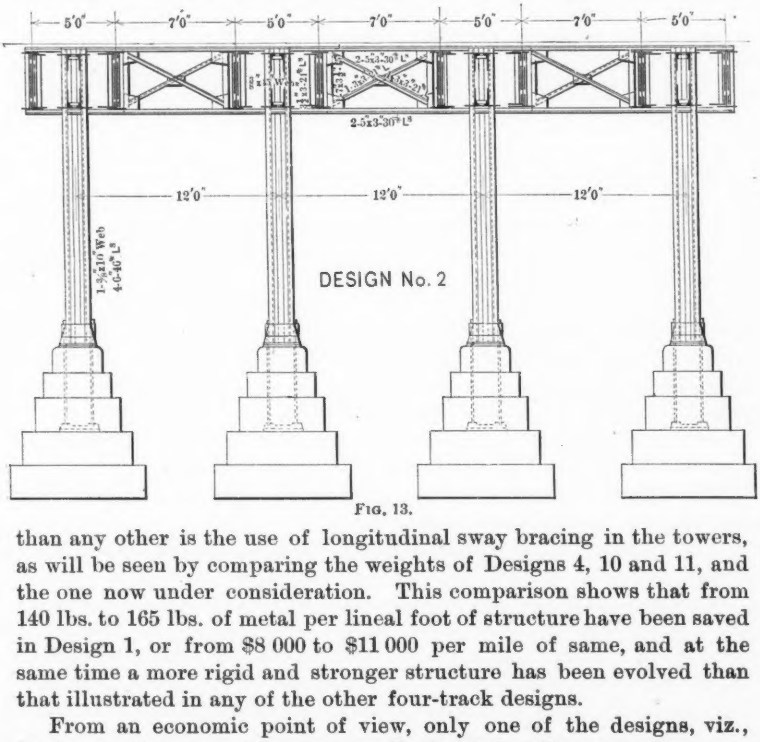


FIG. 13.

than any other is the use of longitudinal sway bracing in the towers, as will be seen by comparing the weights of Designs 4, 10 and 11, and the one now under consideration. This comparison shows that from 140 lbs. to 165 lbs. of metal per lineal foot of structure have been saved in Design 1, or from \$8 000 to \$11 000 per mile of same, and at the same time a more rigid and stronger structure has been evolved than that illustrated in any of the other four-track designs.

From an economic point of view, only one of the designs, viz., Design 3, offers any advantage over Design 1, but there are other considerations which offset this apparent economy in Design 3.

Æsthetics.—This structure is light and airy, and upon the whole presents a very neat appearance; more so, perhaps, than any one of the other designs.

Uniformity of Construction.—The style of construction will be the same throughout, with only very slight alterations at stations and on curves, the double-track structure included. This will not be true of several of the other designs.

Facility of Manufacture and Erection.—The style of column used makes it practicable to do nearly all of the riveting in the shops, the cantilevers and brackets, as before stated, forming a part of the column. As the cross-girders have no direct load to carry whatsoever, they are made very light, and are to be connected to the cantilevers in the field, the rivets necessary to make this connection, together with those connecting the stringers to cantilevers and sway bracing, being the only field rivets required.

The work is all plain and straight, excepting the curved brackets. All parts are made of as few pieces as possible, and there are no large or unwieldly members to handle.

This design will be easier to manufacture and erect than any one of the other designs now under consideration.

Design 2, Fig. 13.

This is similar to Design 1.

Strength.—As far as the strength of the various parts of the structure is concerned, this design is almost the same as Design 1. The same sections are used in the stringers, columns, cross-girders and transverse and longitudinal bracing.

Rigidity.—This design will not be quite so rigid as Design 1, as there are no brackets beneath the cross-girders, and the method of connecting the cantilevers and cross-girders to the columns is not so good, for in Design 1 the cantilevers and columns are all made in one piece; otherwise, the two designs are identical.

Economy.—The cost of Design 2 is the same as that of Design 1, viz., $65 10 per lineal foot (average), including curves.

Æsthetics.—Owing to the omission of the brackets, this design does not appear so well as does Design 1.

Uniformity of Construction.—What was said of Design 1 applies to Design 2 as well.

Facility of Manufacture and Erection.—In this case the cantilevers and cross-girders are riveted up to the columns in the field; this necessitates driving more rivets in the field than in case of Design 1, but all the work is plain and straight, and will be easy to manufacture and erect. Taking it as a whole, this design is not quite so satisfactory as Design 1, and it costs quite as much money.

Design 3, Fig. 14.

Strength.—Design 3, as well as all the others, has been made good and strong in all its details.

Rigidity.—This design is a two-column, four-track structure, with the two outer tracks cantilevered out beyond the columns, which are spaced 24 ft. centers in planes transverse to the structure. While the structure has been designed to be as rigid as is possible with this style of construction, the unequal distribution of load and the lengths of cantilever and girder necessary do not insure the rigidity which is obtained in Designs 1 and 2.

Laterally, the structure is well braced; and, longitudinally, the braced towers are used, as in the preceding designs.

Economy.—This design is a trifle cheaper than Designs 1 and 2, on account of the saving in pedestals, the metalwork costing considerably more, though, than in those designs.

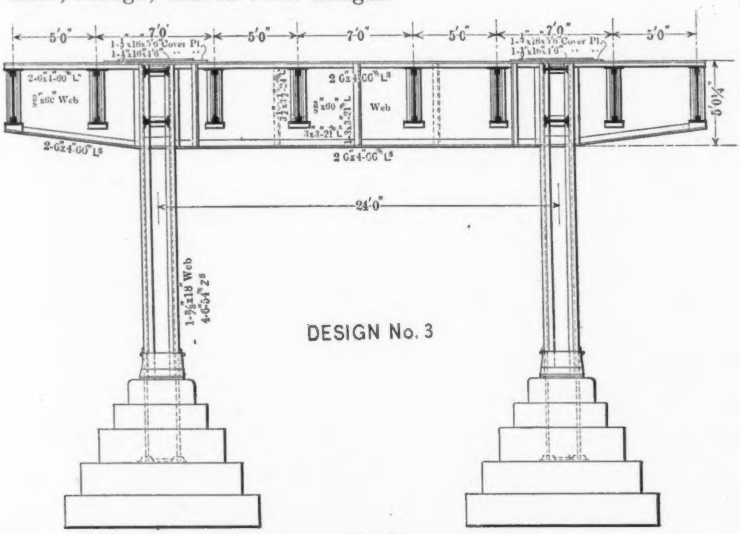


FIG. 14.

Cost of Design 1..................	$65 10
Cost of Design 3..................	64 60
Difference..............	$0 50, or $2 640 per mile.

Æsthetics.—This structure is by no means a good-looking one.

Uniformity of Construction.—In this design in changing from four-track to double-track structure, it will be necessary to change entirely the style of construction, which is not the case in Designs 1 and 2.

Facility of Manufacture and Erection.—In this design all cross-girders and cantilevers must be riveted to the columns in the field, and, owing to the great depth of these girders, this will make this structure difficult to erect. The girders are all heavy and unwieldy, much more

so than in the four-column structures. The work in the shops will be easy.

While the structure is, perhaps, apparently a little more economical than Design 1, it has the disadvantages of being unsightly, of lacking rigidity, and of being difficult to erect.

Design 4, Fig. 15.

General Description.—Design 4 differs from Designs 1, 2 and 3 in the fact that no longitudinal sway bracing is used, but each column is made strong enough to take up the longitudinal thrust coming upon it. The spans through the blocks are about 50 ft. long.

This is a four-column, four-track structure, each column being fixed at top and bottom in planes transverse and parallel to the

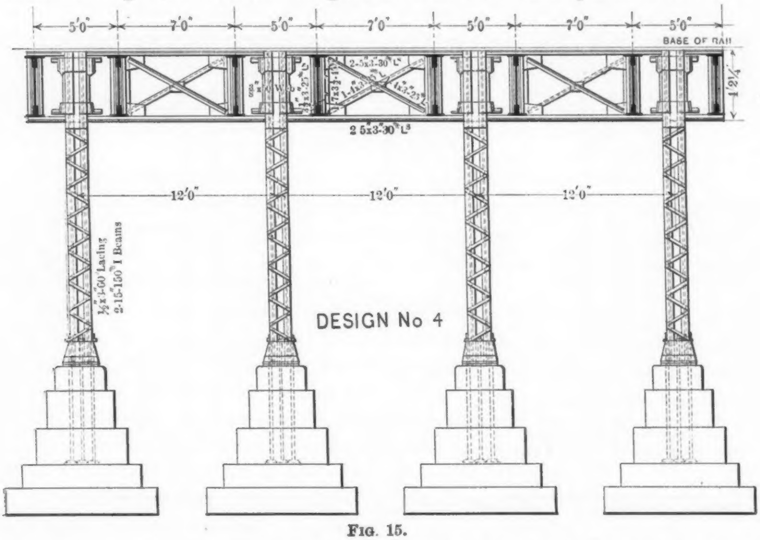


Fig. 15.

structure. The columns are anchored to the pedestals by four anchor bolts instead of two, as in the preceding designs.

Rigidity.—As the only longitudinal rigidity obtained is solely through the efficiency of the columns to resist bending, it is evident that this design will not be as rigid in this direction as Designs 1, 2 and 3. There are no brackets transverse to the structure; hence, it will not be as rigid laterally as Design 1. The stringers are well braced together and to the columns. On curves, transverse sway bracing will be used where permissible, and where it is not, the columns will be strengthened, so as to take care of the centrifugal load.

Economy.—This is the most expensive design yet considered, the average cost per lineal foot being $66 65 instead of $65 10 for Design 1.

Æsthetics.—Design 4 has nothing to commend it from an æsthetic point of view.

Uniformity of Construction—Like Designs 1 and 2, this design has the advantage of being adapted to both double and four-track structures.

Facility of Manufacture and Erection.—This design would be easier to erect than Design 3, but not so easy as Design 1. The shopwork would be somewhat difficult.

Design 5, Fig. 16.

General Description.—This is a two-column, four-track structure, and, like Design 4, has no longitudinal sway bracing. The columns are built up of plates and angles, and are designed to carry the longi-

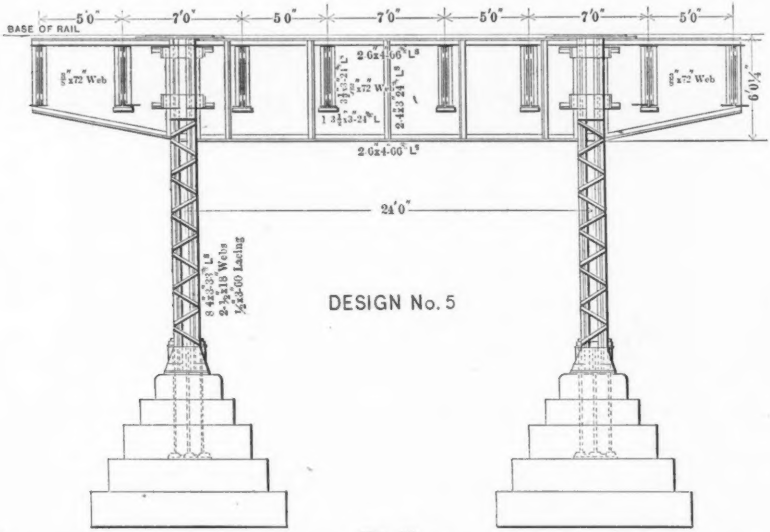


Fig. 16.

tudinal and transverse thrusts due to braked trains and to wind load. The spans are of the same lengths as in Design 4.

Rigidity.—The remarks made under this head for Design 3 apply to Design 5 as well; but, in addition to the defects of the former, Design 5 lacks the longitudinal sway bracing, and so will not be as rigid as Design 3.

Economy.—Design 5 is the most expensive design on the list, the cost per lineal foot being $67 60.

Æsthetics.—Like Design 4 it has no commendable features in this respect.

Uniformity of Construction.—Like Design 3 this style of structure could only be made to apply to the four-track railway.

Facility of Manufacture and Erection.—The style of columns used would be somewhat difficult to manufacture, and the great amount of field riveting would make the erection expensive.

From the foregoing facts it will be seen that this design has several disadvantages and is also very expensive, although it has some good features.

Design 6, Fig. 17.

General Description.—Design 6 is similar to Design 1, but is a double-track structure. The remarks under Design 1 in relation to rigidity, æsthetics, and facility of manufacture and erection apply to this case also.

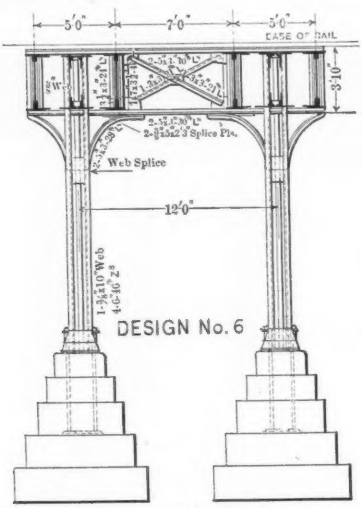


Fig. 17.

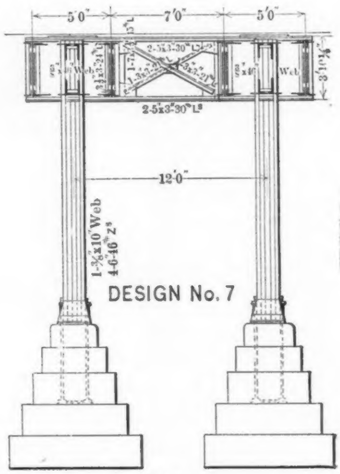


Fig. 18.

Economy.—The cost per lineal foot is $32 65.

Uniformity of Construction.—By using this design for double-track structure and Design 1 for the four-track structure, the design will be the same for columns, stringers, bracing towers, expansion ends, etc., throughout the whole line. If at any time it be considered necessary to convert double-track structure into a four-track structure, it can be done by simply adding a column at each side of the double-track structure, and putting in the additional stringers, cross-girders, and sway bracing.

Design 7, Fig. 18.

Design 7 bears the same relation to Design 2 that Design 6 bears to Design 1. The cost per lineal foot will be $32 65.

Design 8, Fig. 19.

General Description—In this design, which is for double track, the columns are made of four Z-bars, as in Designs 1, 2, 3 and 6, but instead of the columns being directly beneath the center of the tracks, they are placed beneath the outer stringers, thus making the spacing 17 ft. centers, transverse to the structure.

Strength.—The end webs in the cross-girders extend through the columns, forming the webs of the latter at the top, and pass down far enough to form good brackets, thus making the column, end of cross-girder, and brackets all in one piece, which is riveted up solidly in the shop. This makes a very strong connection.

Longitudinal bracing towers are used as in Designs 1, 2, 3, 6 and 7.

Rigidity.—This design is thoroughly braced in all directions, and will be very rigid; but as the columns are attached to the outer string-

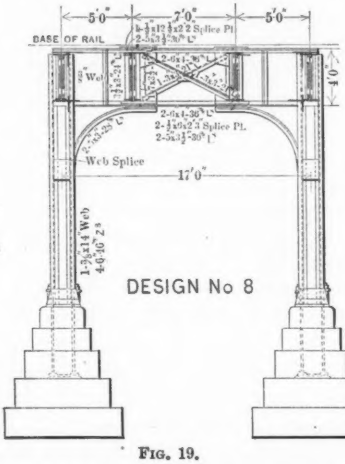


Fig. 19.

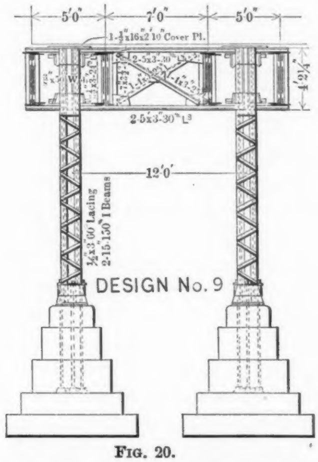


Fig. 20.

ers, and as the inner stringers are supported by the cross-girders, it is probable that there will be some unequal deflection in the stringers; otherwise this design will be as rigid as Design 6.

Economy.—This is the cheapest design on the list for a double-track structure, the average cost per lineal foot being \$32 30, while Designs 6 and 7 each cost \$32 65. This shows a saving of 35 cents per lineal foot, or \$1 850 (nearly) per mile of double track.

Æsthetics.—The cross-section of this design is probably the most æsthetic of any of the designs, and the side elevation at street crossings can be improved by putting in longitudinal brackets beneath the outer stringers.

Uniformity of Construction.—This design necessitates considerable change in the style of construction from that used in the four-track

structure, and it would be difficult ever to convert the double-track structure into a four-track structure in case it should be considered advisable to do so at some future time.

Facility of Manufacture and Erection.—The style of columns and cross-girders used dispenses with nearly all of the field riveting, and will make this a very easy structure to erect. In the shop the work will also be very easy. The lateral system on curves and the stringer bracing used throughout the structure will be easier to connect to the columns and stringers in this design than in any of the other double-track structures now under consideration.

With the exception of the lack of uniformity in construction this design probably offers more advantages than any other for the double-track structure.

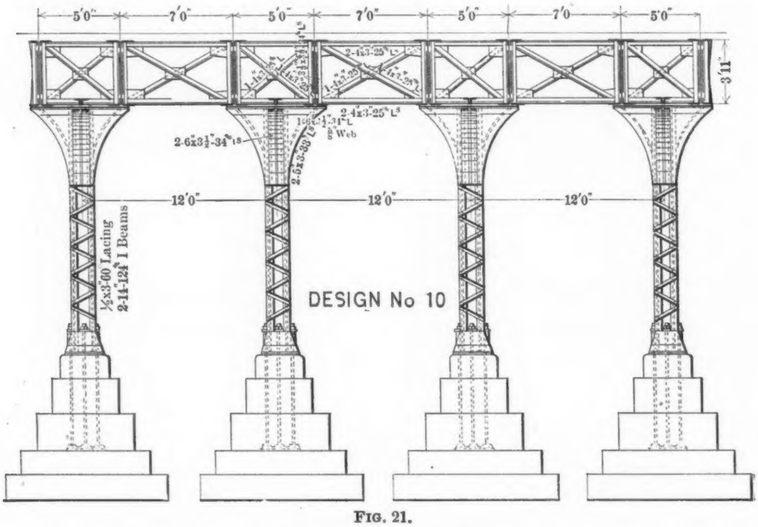


Fig. 21.

Design 9, Fig. 20.

Design 9 is a double-track structure similar in construction to Design 4, and the remarks made under the latter in relation to strength, rigidity, economy, æsthetics, uniformity of construction and facility of manufacture and erection apply to this case also. The cost per lineal foot is $33 31.

Design 10, Fig. 21.

Design 10 is different from any of the designs yet considered, for in all these the columns are carried up to the tops of the cross-girders, while in this the column is carried up only to the plane of the bottom of the stringers, the top of the column being flared out wide enough to receive the two track stringers, which are spaced 5 ft. centers. No

longitudinal bracing is used, so each column is figured to take up in bending its share of the longitudinal thrust.

The columns are made of two I-beams, well laced from the bottom up to the point where the flaring begins, and from this point to the top a large plate is riveted on each of the transverse faces of the column. This design is somewhat similar to the design used on the Metropolitan Elevated Railway of Chicago.

Strength.—Design 10 has been made amply strong in all of its parts.

Rigidity.—As the columns are placed directly beneath the center line of the tracks as in Designs 1, 2, 4, 6, 7 and 9, there will be but little vibration or deflection so far as the vertical loads are concerned, but, as the columns are not carried up to the tops of the stringers and cross-girders, it is impracticable to make the structure rigid against the longitudinal thrust due to braked trains. Longitudinal brackets have been used to fix the upper ends of the columns; but as each of these brackets has to take hold at the center of a small I-beam 5 ft. long, it is evident that the only rigidity that can be procured in this way is dependent upon the efficiency of this I-beam to resist bending, and a very small deflection in the I-beam will permit of considerable deflection in the column. With this bracket and connection, it is not legitimate to call the column fixed at the top. The stringers are well braced together, and the structure would be very rigid laterally, both on tangents and on curves.

Economy.—This design will cost $67 22 per lineal foot, while Design 1 costs but $65 10; hence, Design 1 costs $2 12 less per lineal foot or about $11 200 less per mile than Design 10. The pedestals are more economical in Design 10 than in Design 1, owing to the greater span length used in the former. The additional cost is due to the great amount of metal required to provide for the longitudinal thrust.

Æsthetics.—Design 10 has probably as much to commend it from an æsthetic point of view as any of the designs under consideration.

Uniformity of Construction.—This design, like Designs 1, 2 and 4, can also be used on the double-track structure without any changes in the columns or cross-girders.

Facility of Manufacture and Erection.—This design is very easy to erect, as there is very little riveting to be done in the field. The stringers rest upon the flaring tops of the columns and require only a few rivets to hold them in place. There would be about the same amount of field riveting to be done in this design as in Design 1. There is considerable curved work in both plates and angles in the details at tops of columns, which details are rather complicated; hence the shopwork will be expensive and unsatisfactory.

From the foregoing facts it is evident that Design 10 offers but few advantages and is also an uneconomical structure.

Design 11, Fig. 22.

Nearly all that has been said in regard to Design 10 applies also to Design 11, the principal difference in the two designs being in the section used for the columns. In Design 11 there are two 15-in. channels strengthened by $3\frac{1}{2}$ x 3-in. 23-lb. angles, and near the top the channels are curved outward, so as to provide bearing for the stringers or longitudinal girders. Experience shows that these curved channels are liable to crack.

The cost of Design 11 is exactly the same as that of Design 10. The same provisions are made for longitudinal thrust, but Design 10 would be easier to manufacture, and would be preferable to Design 11.

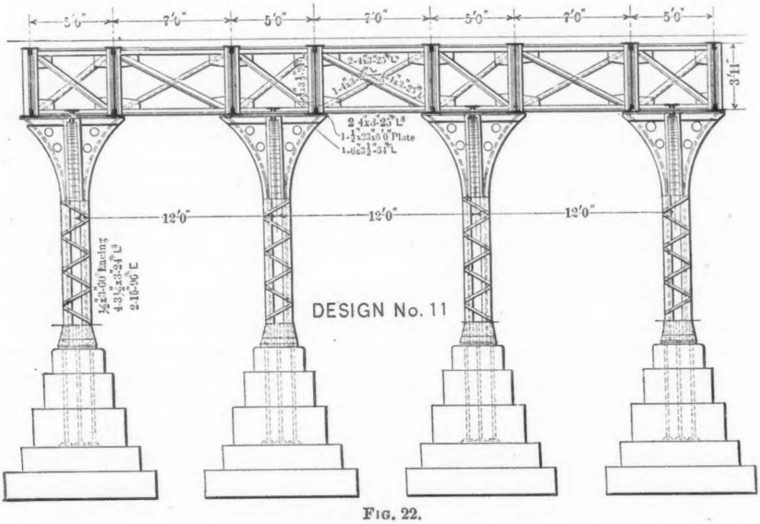


Fig. 22.

Design 12, Fig. 23.

Design 12 is for the alternative route, and is therefore to be placed in the street. Instead of having the columns located in the roadway, as in the Wabash Avenue Extension of the Lake Street Elevated, they will be placed back of the curb lines on the sidewalks, and a heavy cross-girder will span the roadway and support the longitudinal girders, which will be spaced, as in all the other designs, 5 ft. centers, with the two tracks 12 ft. centers. No longitudinal sway bracing can be used, therefore the columns are figured to take up the thrust by bending. The column section will consist of one 15-in. I-beam riveted between two 15-in. channels turned face to face.

Strength.—This design is made very strong, and is thoroughly braced laterally. The columns are each anchored to the pedestals by four anchor bolts which fix their feet, while the tops are fixed by heavy struts extending from the columns to the stringers.

Rigidity.—Owing to the great distance between the columns, transverse to the structure, this design will not be as rigid as Designs 6 and 7, but every precaution has been taken to avoid vibration and deflection. An efficient lateral system has been provided throughout, on tangents as well as on curves, and it will be as rigid a structure as could be expected on this plan.

Economy.—This cannot be called an economical design when compared with the preceding designs for double-track structures, as the

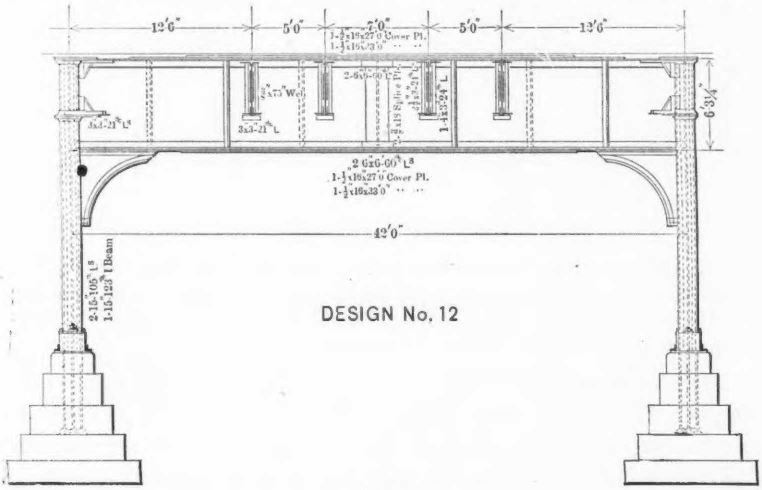


FIG. 23.

total cost per lineal foot amounts to $42, while Design 8 costs but $32 30 per lineal foot. This excessive cost is due to the spacing of the columns and the extra weight of cross-girders occasioned thereby.

Facility of Manufacture and Erection.—This will be a very easy design to manufacture, as it is all straight work; the erection, however, will be much more difficult than that of any of the other double-track structures under consideration, owing to the large number of field rivets to be driven and the great weight of the cross-girders.

Design 13, Fig. 24.

Design 13 is also for the alternative route in case a franchise can be secured permitting the columns to be placed in the roadway. This design is similar to the Wabash Avenue Extension of the Lake

Street Elevated, but plate girders will be used throughout for the stringers. The estimate for Design 13 is based upon the assumption that the columns can be spaced 17 ft. centers on Franklin Street and 22 ft. 8 ins. centers on the remainder of the line.

The average cost of Design 13 would be $36 81 per lineal foot, involving a saving of $5 19 per lineal foot over Design 12, or about $27 400 per mile.

SUMMARY OF COST.

Design.	Weight per lineal foot on tangent.	Weight per lineal foot on curves.	Cost of line per lineal foot.	Cost of line and stations per mile.
1	1 565	1 765	$65 10	$383 728
2	1 565	1 765	65 10	383 728
3	1 590	1 790	64 60	381 088
4	1 700	1 920	66 65	391 912
5	1 750	1 950	67 60	396 928
6	775	875	32 65	210 000
7	775	875	32 65	210 000
8	770	830	32 30	208 544
9	850	960	33 31	213 876
10	1 725	1 950	67 22	394 921
11	1 725	1 950	67 22	394 921
12	1 142	1 182	42 00	267 760
13	916	966	36 81	240 357

In the preceding table there have been assumed four stations to the mile. In the four-track structure one of these is an interior station and the other three are exterior stations, while in the double-track structure all are, of course, exterior stations.

It is in order now to discuss faulty details in existing elevated railroads. This will be done without reference to any road or roads in particular, as the sole object of this discussion is to call attention to important defects in order that they may be avoided in future work.

1.—INSUFFICIENCY OF RIVETS FOR CONNECTING DIAGONALS TO CHORDS OF OPEN-WEBBED, RIVETED GIRDERS.

This defect is more noticeable in old structures than in later ones, especially as the tendency now-a-days is very properly to substitute plate-girder for open-webbed construction. In many of the older elevated roads there is no connecting plate between the diagonal and the chord, but one flange of each of the angles in the diagonal is riveted directly to the vertical legs of the chord angles. This detail involves the use of either two or four rivets to the connection, which is evidently very bad designing, as there should be more rivets used, even if the diagonal stresses do not call for more on purely theoretical

considerations. Where the theoretical number of rivets is very small, additional rivets should be used for two reasons, viz.: First, one or more of the rivets are liable to be loose, and, second, there is nearly always a torsional moment on each group of rivets owing to eccentric connection.

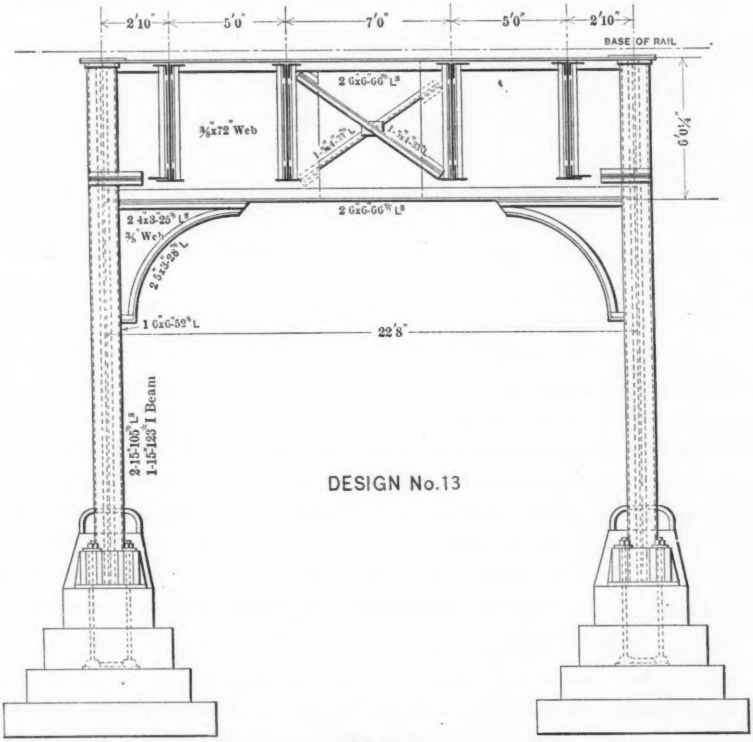


Fig. 24.

2.—Failure to Intersect Diagonals and Chords of Open-Webbed Girders on Gravity Lines.

It is very seldom indeed that the designer even attempts to inter sect at a single point all of the gravity lines of members assembling at an apex. The failure to do so involves large secondary stresses, especially in the lighter members. By using connecting plates, it is always practicable to obtain a proper intersection; and it is always better to do this than to try to compensate for the eccentricity by the use of extra metal for the main members.

3.—Failure to Connect Web Angles to Chords by Both Legs.

Some standard bridge specifications stipulate that in case only one leg of an angle be connected, that leg only shall be counted as acting, although this stipulation is generally ignored by the designer working under such specifications. It is seldom, indeed, that both legs are connected. In order to settle the question of the necessity for this requirement, the author has had made, in connection with his Northwestern Elevated work, a series of tests to destruction of full-size members of open-webbed girders, attached in the testing machine as nearly as practicable in the same way as they would be attached in the structure. It was intended to settle by these tests the following points: first, effect of connecting by one leg only; second, effect of eccentric connection; and, third, the ultimate strength of star struts with fixed ends, each of these struts being formed of two angles. As these tests are not yet finished, their results cannot be given here. The principal deduction to be made from the tests thus far completed is that an equal-legged angle riveted by one leg only will develop about 75% of the strength of the entire net section, while a $6 \times 3\frac{1}{2}$-in. angle riveted through the longer leg will develop about 90 per cent. It is therefore more economical for short diagonals to use unequal-legged angles connected by the longer leg than to employ supplementary angles to try to develop the full strength of the piece. In fact, the experiments made up to date indicate that these supplementary angles will not strengthen the diagonal essentially. However, further experiments may show the contrary.

4.—Failure to Proportion Top Chords of Open-Webbed Longitudinal Girders to Resist Bending from Wheel Loads in Addition to Their Direct Compressive Stresses.

This neglect is common enough in the older structures, and the fault is a serious one, although the stiffness of the track rails and that of the ties tend to distribute the load and thus reduce the bending.

5.—Insufficient Bracing on Curves.

Too often in the older structures the curved portions of the line are no better braced than are the straight portions. A substantial system

of lateral bracing on curves extending over the entire width of the structure and carried well into the tops of the columns adds greatly to the rigidity of the structure, and, consequently, to the life of the metalwork.

6.—Insufficient Bracing between Adjacent Longitudinal Girders.

The function of the bracing between longitudinal girders is an important one, for it is the first part of the metalwork to resist the sway of trains. Not only should the top flanges of adjacent girders be connected by rigid lateral bracing, but the bottom flanges should be stayed by occasional cross-bracing frames, one of the latter being invariably used at each expansion end of each track.

7.—Pin-Connected Pony Truss Spans and Plate Girders with Unstiffened Top Flanges.

These defective constructions are noticeable in some of the older lines, but, fortunately, not often in the newer.

What the ultimate resistance of the pony-truss structure is no man can tell without testing it to destruction; but in the opinion of most engineers it is much less than it is assumed to be by those designing pony-truss bridges.

8.—Excess of Expansion Joints.

Too many expansion joints in an elevated railroad are nearly as bad as too few. In the former case the metal is overstrained by the vibration induced by the lack of rigidity, while in the latter case it is overstrained by extreme variations of temperature. There are elevated roads in existence with expansion joints at every other bent, and there is one with them at every bent. For long spans there should be expansion provided at every third bent, and for short spans at every fourth bent.

9.—Resting Longitudinal Girders on Top of Cross-Girders Without Riveting Them Effectively Thereto.

This is by no means an uncommon detail, especially in the older structures. It is conducive to vibration, and its only advantages

are ease of erection and a cheapening of the work by avoiding field riveting.

10.—Cross-Girders Subjected to Horizontal Bending by Thrust of Trains.

The resistance that can be offered by a cross-girder to horizontal bending is very small; nevertheless, cross-girders are rarely protected from the bending effects of thrusts of trains. What saves these cross-girders from failure is the fact that continuity of the track tends to distribute the thrust over a number of bents. Nevertheless, it is not legitimate to depend on this fact, for, especially on sharp curves, the tendency is to carry the thrust into the ground as directly as possible. In the author's opinion the only proper way to provide for this thrust is to assume that 20% of the greatest live load between two adjacent expansion points will act as a horizontal thrust upon the columns between these two expansion points; and all parts of the metalwork should be proportioned to resist this thrust properly.

By running a strut from the top of each post diagonally to the longitudinal girder at a panel point of its sway bracing, the horizontal thrust is carried directly to the post, and a horizontal bending moment on the cross-girder is thus prevented. Such construction should invariably be used where the conditions require it.

11.—Cutting Off Columns Below the Bottom of Cross-Girders and Resting the Latter Thereon.

This style of construction, which until lately was almost universal, is extremely faulty in that there is no rigidity in the connection, and the column is thus made more or less free-ended at the top.

It has been said that no harm is done to the column by making it free-ended, as it can then spring better when the thrust is applied. Unfortunately this reasoning is fallacious, because the few unfortunate rivets which connect the bottom of the cross-girder to the top of the column tend to produce a fixed end, and are, in consequence, racked excessively by the thrust of the train. In all cases the column should extend to the top of the cross-girder and should be riveted to it in the most effective manner practicable.

12.—Paltry Brackets Connecting Cross-Girders to Columns.

Brackets are often seen composed of a couple of little angles and attached at their ends by two or three rivets. Such brackets are merely an aggravation, and are sure to work loose sooner or later. Although it is impracticable to compute the stresses in this detail, nevertheless, good judgment will dictate the use of solid webbed brackets riveted rigidly to both cross-girder and column so as to stiffen the latter and check the transverse vibration from passing trains.

13.—Proportioning Columns for Direct Live and Dead Loads and Ignoring the Effects of Bending Caused by Thrust of Trains and Lateral Vibration.

The practical effects of this fault can be seen to best advantage by standing on one of the high platforms of one of the elevated railroads in New York City. The vibration, by no means small, from an approaching train can be felt when it is yet at a great distance. Some may claim that this vibration is not injurious; but they are certainly wrong, for what does it matter so far as the stress in the column is concerned whether the deflection be caused by vibration or by a statically applied transverse load, so long as the amount of the deflection is the same in both cases. It takes metal, and considerable of it, to make columns strong enough to resist bending properly, and a sufficient amount should be used to attain this end.

14.—Omission of Diaphragm Webs in Columns Subjected to Bending.

If the diaphragm web be omitted in such a column, reliance must be placed on the lacing to carry the horizontal thrust from top to bottom. But even if the lacing figure strong enough to carry it, which is unusual, it is wrong to assume it so, for the reason that one loose rivet connecting the lacing bars will prevent the whole system from acting, as will also a lacing bar that is bent out of line. Decidedly every column that acts as a beam also should have solid webs at right angles to each other.

15.—Ineffective Anchorages.

On account of both rigidity and strength every column ought to be anchored so firmly to the pedestal that failure by overturning or rup-

ture would not occur in the neighborhood of the foot, if the bent were tested to destruction. The flimsiness of the ordinary column-foot connection is beyond description.

16.—Column Feet Surrounded by and Filled with Dirt and Moisture.

The condition of the average column foot is simply deplorable. This is caused by failing to raise it so high above the street as to prevent dirt from piling around it, and by omitting to fill its boxed spaces with concrete. When rusting at a column foot is once well started, it is almost impossible to stop it from eating up the metal rapidly.

17.—Insufficient Bases for Pedestals.

False ideas of economy on the part of projectors and indifference on the part of some unscrupulous contractors occasionally cause the use of pedestal bases altogether too small for the loads that come upon them, especially where the bearing capacity of the soil is low. The result is sunken pedestals and cracked metalwork. In figuring the pressure on the base of the pedestals it is not sufficient to recognize only the direct live and dead loads, but it is necessary also to compute the additional unequal intensities of loading caused by both longitudinal and transverse thrusts.

Æsthetics.

In relation to æsthetics in the designing and construction of elevated railroads something may be said, although but little has been done. The extra cost of decorating an elevated structure is certainly considerable, and on this account projectors are chary of attempting to do more than make the work strong and durable, preferring to let the appearance take care of itself. Notwithstanding this, the careful designer can generally manage to make his construction more or less sightly without adding materially to the expense. This the author attempted to do in both the Northwestern and the Loop. It is for others to say whether he has succeeded or not. At the Diversey Street and Sheridan Road crossings of the Northwestern Elevated some extra ornamentation was compulsory, so it was put in at increased expense; but elsewhere no extra money was expended on appearance.

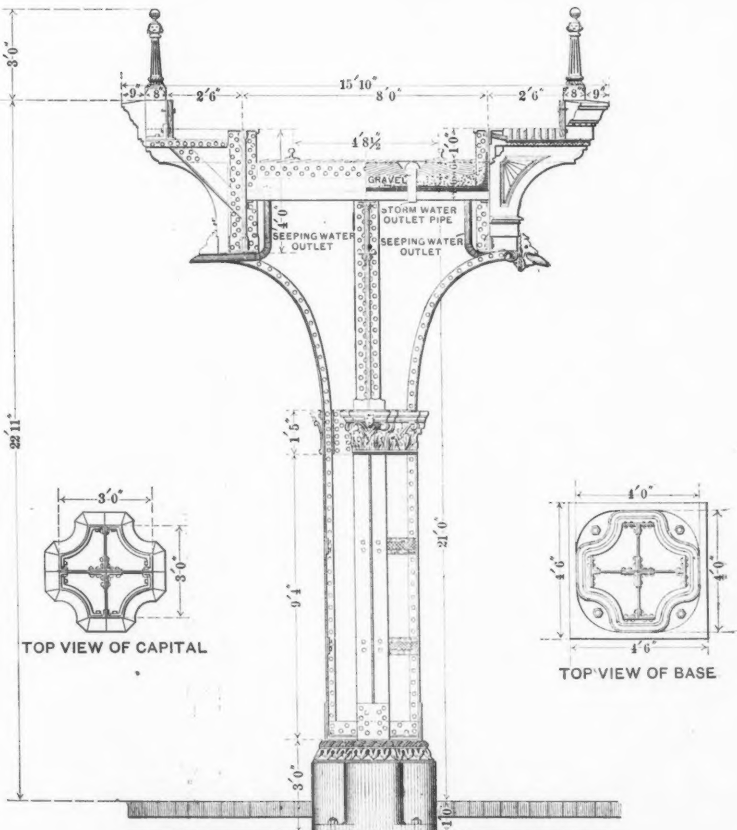

3′ 0″
15′ 10″
9″
8″
2′ 6″
8′ 0″
2′ 6″
8″
9″
4′ 8½″
1′ 0″
GRAVEL
STORM WATER
OUTLET PIPE
4′ 0″
SEEPING WATER
OUTLET
SEEPING WATER
OUTLET
22′ 11″
1′ 5″
21′ 0″
9′ 4″
3′ 0″
1′ 0″
3′ 0″
3′ 0″
TOP VIEW OF CAPITAL
4′ 0″
4′ 6″
4′ 0″
4′ 6″
TOP VIEW OF BASE

FIG. 25.

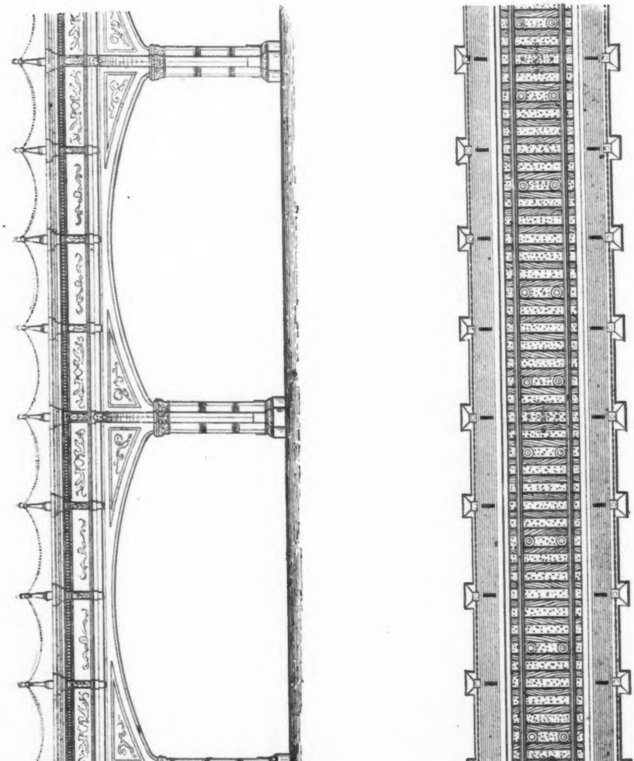
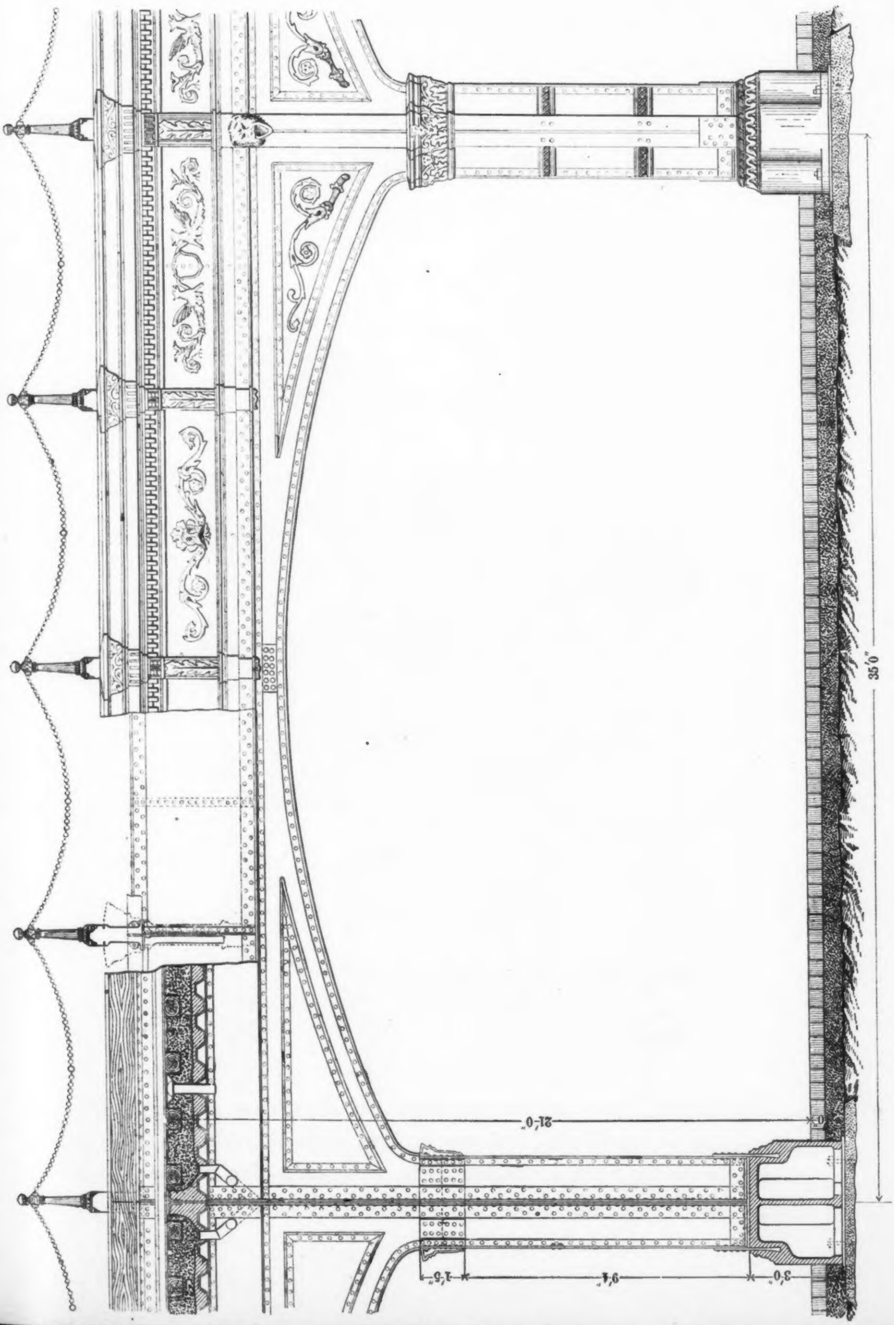


Fig. 26.


35′ 0″
21′ 0″
1′ 5″
9′ 4″
3′ 0″

Some time before the Northwestern Elevated was contemplated, and while several parties were trying to obtain concessions for a down-town loop, the author made a special study of an æsthetic type of structure

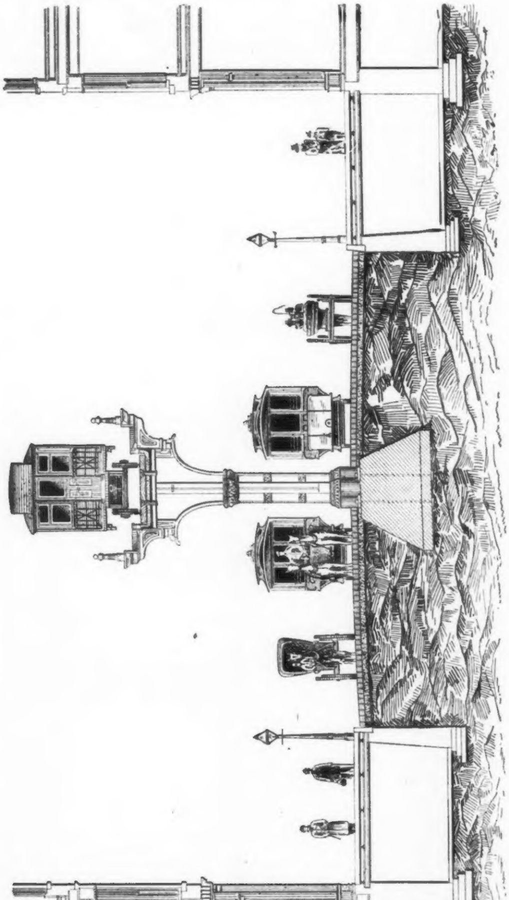


Fig. 28.

for this locality, in which the consideration of expense cut no figure. The result of his studies is shown in Figs. 25 to 29, inclusive, Fig. 25 a cross-section of such a structure, Fig. 26 being a plan and elevation

of a single-track railroad, Fig. 27 a side elevation showing some of the details of construction, Fig. 28 a cross-section of a street with a road of this type, and Fig. 29 a cross-section of the same road with

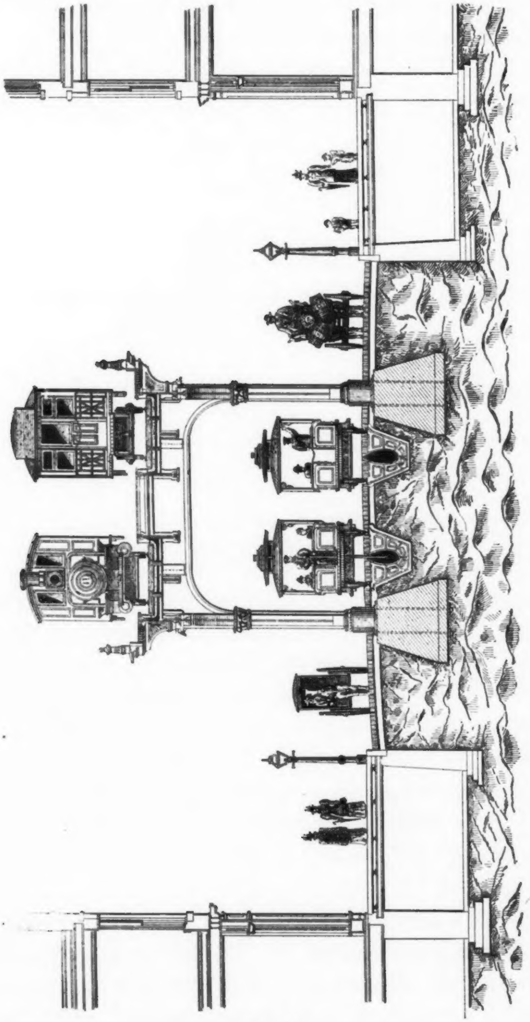


FIG. 29.

a double-track elevated railroad. These designs involved not only appearance, but comparatively noiseless operation and freedom from dripping of water on the people beneath the structure. Although no

line was built according to these drawings, they have, notwithstanding, proved of practical utility in several ways; and the author now offers them to the engineering profession as his idea of what an elevated railroad for a large city should be where expense is no object and where appearance is the great desideratum.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS.

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WIND PRESSURES IN THE ST. LOUIS TORNADO.

By JULIUS BAIER, Assoc. M. Am. Soc. C. E.

TO BE PRESENTED MARCH 3D, 1897.

Very destructive tornadoes have fortunately been infrequent, but the possibility of their occurrence at almost any time cannot be entirely overlooked in the design of structures of great magnitude and cost that may be exposed to their action.

On May 27th, 1896, St. Louis was visited by a tornadic storm that caused a loss of 255 lives and the destruction of property to the amount of $12 000 000. Much of the damage was the result of the direct action of the wind, and a few opportunities occurred to determine the intensity of the wind pressures which prevail in such storms.

This paper is presented mainly with the object of placing on record some definite estimates made by the author of the force exerted by the wind on several structures of known stability that failed under its action, and some further characteristic examples of destruction that

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*

will be indicative of this force, even if its intensity cannot be definitely measured.

A study of the work of the tornado in some detail emphasized certain features as to the nature and action of the wind as a destructive agent, which appeared to be further corroborated by various experimental results.

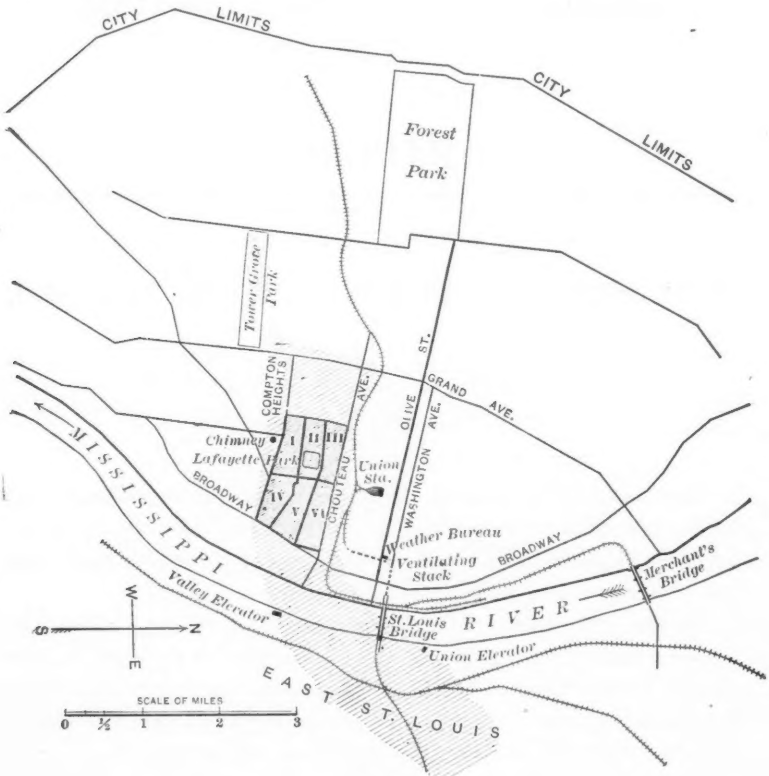

Fig 1.

The possible effects of extreme wind pressures on high buildings will no doubt be variously estimated. The author has presented some conclusions that appear to follow logically from the evidence.

I.—General Conditions.

The storm entered St. Louis from the west, progressed eastwardly through the city at some distance south of the central business section,

crossed the Mississippi River and continued in a northeasterly direction through East St. Louis. The path of the storm, as marked by its destructive effects is indicated by the shaded section on the map, Fig. 1.

The meteorological conditions which attended the storm are given in

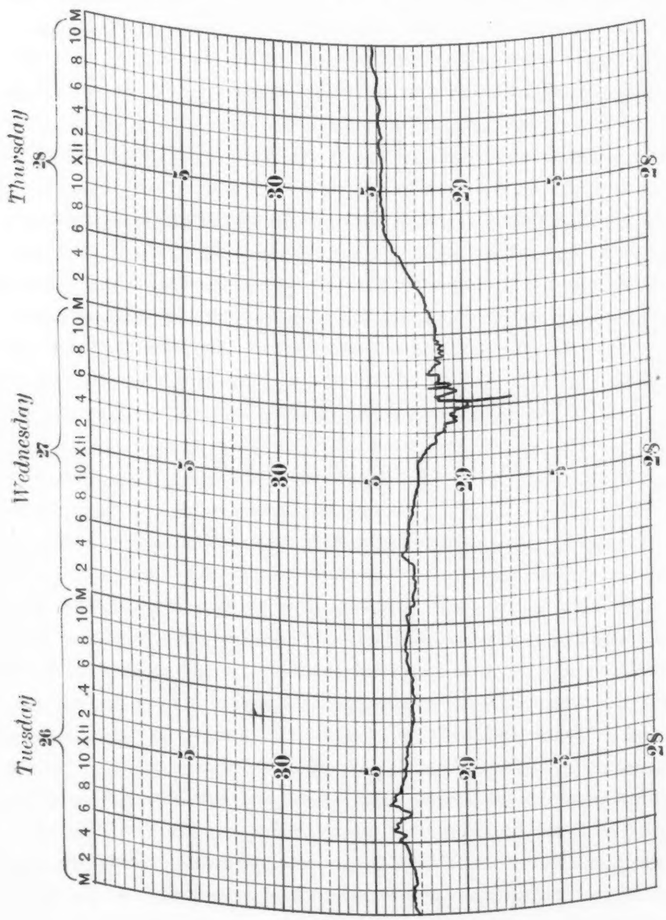

Fig. 2.

the appendix as abstracted from the report of Mr. H. C. Frankenfield, Local Forecast Official in charge of the Weather Bureau Station. The latter is situated in the heart of the city, about a mile from the center of the path of the tornado.

The most marked feature of the storm was the reduction in the atmospheric pressure. The copy of the barograph trace on Fig. 2 is the record of the self-registering aneroid barometer at the station, and shows the general fall of pressure and comparatively low reading during the storm. The recorded pressures shown should have 0.6 in. added to them, to reduce to the sea-level datum. The fluctuations before and several hours after the storm indicate the unstable condition and greatly disturbed state of the atmosphere. As a matter of general interest the barometric record of the tornado which passed over Paris, France, on September 10th, 1896, is reproduced in Fig. 3. While noting the similarity of the lines, it is necessary to bear in mind that while the Paris Observatory was directly in the path of the storm, the records of the instruments at St. Louis show the conditions about a mile from the center of action and can give but an indication of the disturbance in the elements at that point. There was no barograph at the Louisville station on the day of the tornado there, March 27th, 1890.

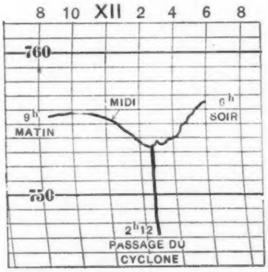

Fig. 3.

There is no record of the pressure in the path of the tornado except the reading of the aneroid barometer referred to in Mr. Frankenfield's report. This instrument was hanging at a window on the first floor of the house, and as the storm struck the building the index was noticed to be almost opposite to its usual position, or pointing nearly downward. As afterwards ascertained, this would give a reading somewhere between 680 mm. and 690 mm., and it is assumed here at an average of 685 mm. The author has since tested this instrument, comparing its readings at reduced pressure under an air receiver with a mercury gauge, and found the corrected pressure for a reading of 685 mm. to be 671 mm., equivalent to 26.63 ins. on the mercurial barometer locally, or 27.23 ins. reduced to sea level. This would give a difference in barometric pressure of 2 13 ins. below the lowest reading recorded at the time of storm at the Weather Bureau Station, and about 2.4 ins. below the average reading which prevailed at that point for some time preceding the storm, the latter reading being, however, about 0.23 in. lower than at noon. The house had the roof and part of the upper

walls taken off, windows broken, and the contents very generally blown about by the winds, but this damage occurred afterward. The barometer was accidentally noted, but not read, immediately preceding the general confusion and excitement due to the extreme severity of the storm, and the result can probably be accepted with a possible error of say a tenth or two either way.

While the self-registering barometers record the variations of pressure corresponding to inches of mercury on the gauge to a full-size scale, the small scale of the abscissas allows but an approximate estimate as to the exact time of occurrence or the rate of this change. The horizontal scale being about 15 hours or 900 minutes per inch, 0.01 in., or about the thickness of a line, is equal to 9 minutes in time. A variation of pressure requiring a few minutes for its completion would leave the same record as one taking place in a few seconds.

The anemometer record shows the passage of 13 miles of wind in about 12 minutes; of this, a little over 6½ miles passed in 5 minutes, a rate of about 80 miles an hour observed, giving, when properly corrected, an actual velocity of about 62 miles per hour. The general direction was towards the south, into the storm center.

There are indications of a strong downward component to the wind at a point about 800 ft. northeast of the Weather Bureau Station at the ventilating stack* over the tunnel by which the trains over the St. Louis Bridge enter the city. The ventilating fan placed at the bottom of the stack, which is used to exhaust the smoke from the tunnel, was checked and the engine slowed down from its usual speed of 80 to 90 revolutions per minute to about one-third or one-fourth of that speed, for an estimated period of 10 to 15 minutes, by the pressure of the air above. The stack is 110 ft. high, 15 ft. in diameter and flared to 30 ft. diameter at the base to admit the fan; the latter is 20 ft. in diameter, revolves in a horizontal plane, and is directly coupled to the engine shaft by beveled gear. On opening the manhole just above the level of the fan to locate the trouble, the engineer was thrown across the room by the rush of escaping air.

The foregoing facts, coupled with the general indication and testimony of strong winds from the west, north and east, with the prevailing direction towards the general center of the storm, are well established. There was an apparent meeting of heavy clouds coming from

* See "Ventilation of Tunnels," N. W. Eayrs, *Transactions*, Vol. xxiii, p. 293.

opposite directions, followed by general darkness and a general storm of more or less violence. There were no funnel-shaped clouds seen so far as the author knows.

The general conditions which prevailed within the storm at its height were a total darkness except where relieved by the lightning and grounding of electric wires; furious wind, filled with flying missiles, that blew in turn apparently from every direction in puffs and gusts of extreme intensity and a continuous roaring noise that drowned every individual sound; the shock and crash which must have attended the fall of the Valley Elevator was not noticed by men within 100 ft. of the building. The time the storm occupied in passing any one point is generally given as very short, though this would depend, of course, upon the location of the observer. In one instance in a street car, at about the center of the area devastated by the storm, the time, noted by the watch, was between four and five minutes. During this interval the darkness was complete, and the wind blew in successive gusts and blasts that shook the car until it seemed in continuous motion.

The attendant confusion, terror and danger, and the immediate necessity of looking for shelter and personal safety, rendered all other matters of secondary importance, and, in general, little is known of the storm except its results. The full extent of the damage was often unknown, even to occupants of the house until the storm was over. When the destruction was noted, it was nearly always observed to be due to the successive action of the wind.

The débris, as a rule, offered but a confused and conflicting testimony as to the general direction of the wind. The great extent of the destruction, the immense volume of material moved, the confused condition due to the successive blowing about by the wind, and also the promptness with which much of the material was moved and piled up by corporations and citizens in clearing the streets and their property, largely destroyed the value of any deductions as to the successive action of the wind.

The great bulk of the material was carried only a short distance, from a few feet to several hundred, and there was apparently a marked absence of that continued carrying power of the wind so frequently found in tornadoes. This may have been due to the difficulty of identification, as any object carried a long distance would scarcely be

missed where it came from and not noticed or recognized where it fell, or such fact would probably be known only to a few persons.

There are members of this Society in St. Louis who, either from personal experience in the tornado or from immediate opportunities of noting results at the destruction of their homes, can give a more detailed account of results than can possibly be done by the author. A record of the evidences of extreme velocity or pressure of the wind, of which there were innumerable instances, would be of special interest if well verified. One evidence is afforded by a piece of pine plank driven by the wind through the $\frac{5}{16}$-in. web of a plate girder on the approach to the St. Louis Bridge, in East St. Louis. The uncertainty as to whether the plank was a detached piece or was fastened to a heavier frame at the moment of impact precludes even the most approximate estimate as to force or velocity.

A general inspection of the buildings brings out the following average characteristic features. The extreme force of the wind was generally confined to upper stories and roofs. The intensity of this force must have been extremely variable, not only as exerted on adjacent properties, but on a single building. There was very general evidence of the destructive force being exerted from the inside.

The total number of buildings destroyed or seriously damaged by the storm in the city of St. Louis, as shown by the records in the Assessors' office, is 7 263. Of these 321 were totally wrecked. The number of houses slightly damaged that can be repaired at an average cost of $75 is 1 249, making a total of 8 515.

Aside from actual inspection, only photographs can convey any adequate impression of the appearance of these wrecked buildings. The church in Fig. 1, Plate I, has been selected as average example of maximum destruction, both as to intensity and area covered, the extreme destruction being generally very much localized. Instances of entire physical destruction are very few and nearly always due to a collapse on account of very old and weak construction; in general the damage is confined to the roofs and upper walls of the houses. The building in the foreground and the one on the right, in Fig. 2, Plate I, and the church in Fig. 1, Plate II, are cases of partial destruction presented to show some characteristic results of the action of the wind.

The general maximum destruction covers an area from 4 000 ft. to 6 000 ft. wide and nearly 3 miles long, lying immediately south of the central part of the city in St. Louis and extending across the river into East St. Louis. There was in addition much damage in several directions towards the west and at various places on all sides of this area. With the exception of a line of factories and industrial plants near the railway on the north and the river on the east, almost the entire area affected in St. Louis is used for residence purposes. A comparatively small section at the western limit and around Lafayette Park is built up with costly private residences. The rest of the buildings are of the cheaper class of brick dwellings, flats, tenements, and small factories, two and three stories high, built in the solid rows common in large cities, with only an occasional church, school or large commercial building standing above the general level. The western section is comparatively new, the eastern part from thirty to sixty years old, with some buildings along the river front that are still older.

Tables Nos. 1 and 2 show approximately the character of the buildings and the extent of the damage in a part of the district where the effect of the tornado was greatest. The district for which this data was compiled, extending from Broadway to California Avenue and from Chouteau Avenue to Russell Avenue, is enclosed by heavy lines on the map, Fig. 5, and divided into six sections. It is from 4 000 to 4 600 ft. wide, and 7 300 to 9 000 ft. long, covering an area of 1.33 square miles, and is divided into 183 city blocks about 260 × 300 ft., or double that size. The entire area is almost solidly built up, having a total number of 4 090 buildings, an average of about 22 per block; there are but 21 blocks having 10 houses or less per block.

TABLE No. 1.

RATIO OF DAMAGE TO TOTAL VALUE OF HOUSE.												
Value.	No damage.		0 to ¼		¼ to ½		½ +		Total Loss			
	No.	Per-cent.	No.	Per-cent.	No.	Per-cent.	No.	Per-cent.	No.	Per-cent.	No.	Per-cent.
$1 500 and less..	393	26	488	31	422	27	109	7	125	8	1 537	100
$1 500 to $3 000..	451	26	812	47	317	18	97	6	52	3	1 729	100
$3 000 and over..	210	25	390	42	145	18	61	7	18	2	824	100
Total	1 054	26	1 690	41	884	22	267	7	195	5	4 090	100

FIG. 1.

FIG. 2.

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TABLE NO. 2.

Section.	No. City Block.	No damage.		0 to ¼		¼ to ½		½ +		Total Loss.		
		No.	Per-cent.	No.	Per-cent.	No.	Per-cent.	No.	Per-cent.	No.	Per-cent.	No.
I......	22	91	18	237	47	120	24	38	7	21	4	507
II.......	16	26	7	125	36	114	23	52	15	31	9	384
III.......	30	135	20	217	32	201	29	71	10	63	9	687
IV......	38	233	32	321	44	135	19	18	2	16	2	723
V...	42	185	27	288	43	157	23	25	4	17	3	672
VI......	35	384	33	502	42	157	14	63	5	47	4	1 153
Total...	183	1 054	26	1 690	41	884	22	267	7	195	5	4 090

In Table No. 1 the buildings are grouped according to their value; in Table No. 2 they are given according to locations. Sections 2 and 3, embracing Lafayette Park and the adjacent property, show the heaviest destruction. The Assessors' lists from which the tabulations were made show that the 195 buildings totally wrecked are distributed in 72 blocks; that 31 of these blocks have each only one house totally destroyed, and the other 41 blocks have each from two to ten houses totally destroyed. The 1 054 houses not seriously injured are distributed over 153 blocks, there being 30 blocks in which no house escaped. In 19 blocks only one house in each escaped serious damage; in 34 blocks one-half of the houses, and in 11 blocks three-fourths of the houses, in each escaped. Throughout the path of the storm the buildings and wreckage show evidence of extreme and sudden variations in the intensity of the wind pressure. A striking example of this is a little pavilion left standing in Lafayette Park, on a slight elevation above the general level at a point where the broken and uprooted trees show the full force of the storm. A straw-thatched roof held in a light wire netting and perched on six uprights planted in the earth and stiffened by a few rustic braces, it would seem a most inviting mark for the wind, but except for some damage due to the falling limbs of adjacent trees, it stands uninjured.

II.—FORCE OF THE WIND.

The St. Louis Bridge.—The main damage sustained by the St. Louis Bridge was confined to the upper section of the masonry approach immediately adjoining the east abutment of the bridge proper.

The details of the construction of this part of the bridge are shown in Fig. 4. The structure is double decked, the highway floor, which is the full width of the bridge, being carried immediately above the railway tracks by cross-girders resting on the masonry side walls. These walls are 30 ins. thick, and are pierced by 21 arched openings, leaving a row of pillars 30 ins. square, spaced 8 ft. 7¼ ins. between centers. The masonry is built of sandstone, and is all first-class dimension work, all the blocks being the full thickness of the wall and laid with the bond shown on the drawing.

The highway floor is of timber carried on iron cross-girders. The sidewalks are 10 ft. wide, built of 3-in. planking, supported on 3 x 14-in. stringers, with a line of 7 x 14-in. stringers on the outside, to which the iron handrail is securely bolted. The roadway is 34 ft. wide, and consists of cypress block paving, 4½ ins. deep, laid on 3-in. cypress planking carried on 26 lines of 6 x 14-in. pine stringers. The planks are laid crosswise of the structure in two 17-ft. lengths, bringing all joints on the center line, and are spiked to the stringers. The latter are in lengths of two panels, and laid with lap joints. Six lines of these stringers are secured to each of the iron cross-girders by two ½-in. bolts with special washers.

The iron girders carrying the floor are centered over the pillars of the side walls. Seven of these girders near each end were heavy 15-in. rolled I-beams supported at their central points by longitudinal girders, one at each end, to which they were fastened by braces. These longitudinal girders were 42 ins. deep and were supported on posts from the railway floor beneath, except the west end of the west girder, which was seated in a narrow recess cut into the masonry abutment for that purpose. Although the girder extended 2 ins. into this pocket, and the latter was 40 ins. deep, there was no abrasion of any kind on the stonework. The girder must have been raised out of the pocket by a straight lift, this being possible, as the fastenings of the floor to the iron girders were of sufficient strength to raise the weight of the latter. The 15-in. I-beams each weighed about 3 000 lbs. and the longitudinal girders each 13 000 lbs. To provide clearance and headroom for a cross-over in the railroad tracks, the seven girders near the center were made to span the full distance. They were built beams with 27-in. webs, and weighed about 8 000 lbs. each.

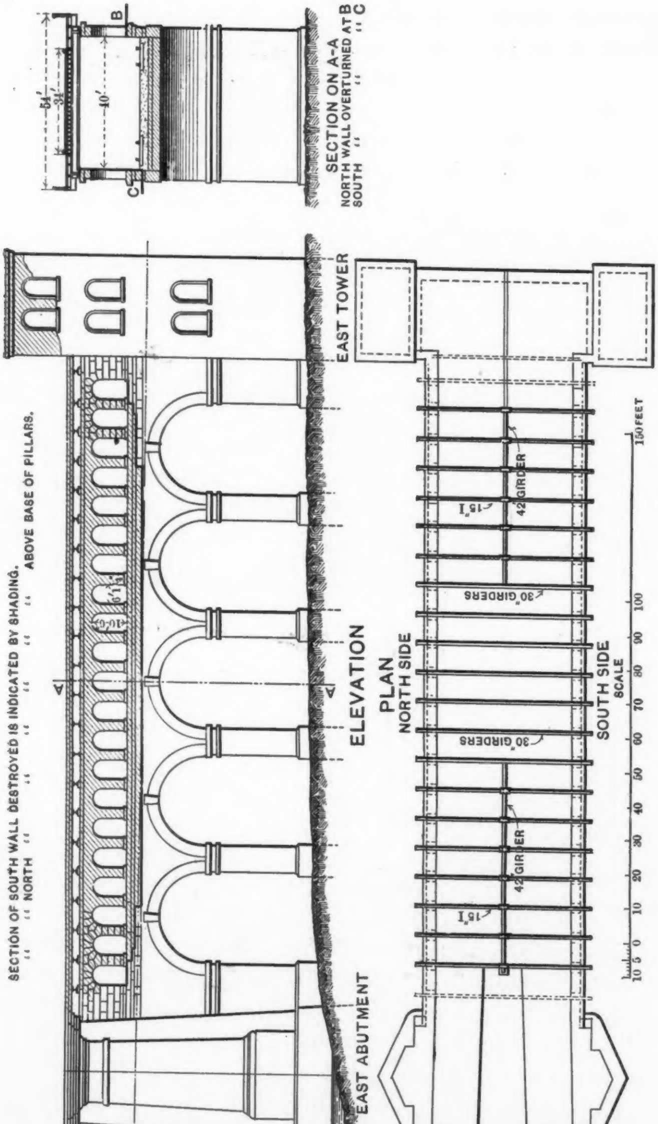
SECTION OF SOUTH WALL DESTROYED IS INDICATED BY SHADING.
" " NORTH " " " " " ABOVE BASE OF PILLARS.
SECTION ON A-A
NORTH WALL OVERTURNED AT B
SOUTH " " C
ELEVATION
EAST TOWER
EAST ABUTMENT
PLAN
NORTH SIDE
SOUTH SIDE
SCALE
42" GIRDER
30" GIRDERS
15" I
150 FEET

FIG. 4.

During the storm a rush of wind from the northwest carried away 200 lin. ft. of the highway floor with the girders attached, and overturned both sidewalls for a length of 180 ft. The highway floor for a distance of 100 ft. on the main span immediately adjoining this section was disturbed by the wind, the sidewalk being carried away, and the north half of the roadway being lifted and partly moved out of its place. The extent of the damage to the arcade is indicated by the shading in Fig. 4, and is shown in Fig. 2, Plate II, which is a view taken from the south side looking northwest, several days after the storm, the trestle work on the right being a temporary support for the roadway in process of erection.

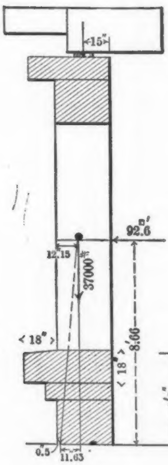

FIG. 5.

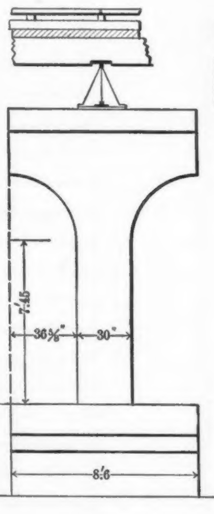

FIG. 6.

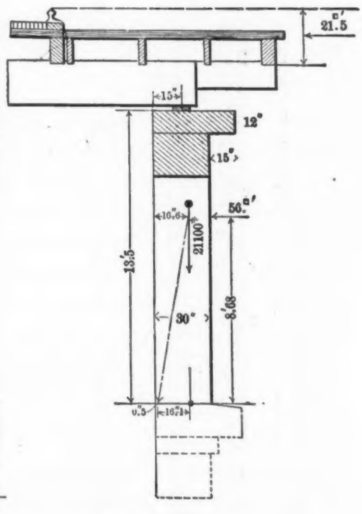

FIG. 7.

The following computations of the stability of the structure are made for two assumptions. First, that the floor was lifted, and then the walls overturned separately. Second, that the walls were overturned together with the full weight of floor upon them. In each case the wind is assumed to act at right angles to the face of the wall. The weight of the sandstone was found by the actual weighing of two blocks to be 140 lbs. per cubic foot. The cypress timber from an average of several planks was found to weigh 3½ lbs. per foot B. M. The pine was assumed at 2½ lbs. per foot B. M.

FIG. 1.

FIG. 2.

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(a) N

(b) Sc

The overhang of the coping and sill-course brings the center of gravity of the wall near the outer face. This very markedly increases the stability as against falling inward and reduces it against falling outward.

The general dimensions and details of one panel are given in Figs. 5, 6 and 7. The weights, area exposed and centers of gravity have been computed from data given there. The limiting position for the center of pressure is taken $\frac{1}{2}$ in. from the edge as the stone shows very little crushing.

Floor Lifted and Walls Overturned Separately.

In estimating the weight of the floor, the handrail is to be included in the weight of the sidewalk, and the girders in that of the roadway. This gives the following weights per square foot of surface:

Sidewalk, including handrail		22.1 lbs. per square foot.
Roadway, end panels—timber	43.1	
girders	16.6	
	——	59.7 " " "
Roadway, center panels—timber	43.1	
girders	27.3	
	——	70.4 " " "

Stability of Walls.

Let P = total wind force per panel.

p = pressure per square foot.

(*a*) North Wall.

Moment stability $= 21\,100 \times \frac{16.1}{12} = 28\,309$ ft.-lbs.

Moment overturning $= P \times 8.68$

For equilibrium $P = \frac{28.309}{8.68} = 3\,261$ lbs.

$$p = 3\,261 \times \frac{1}{56} = 58.2 \text{ lbs. per square foot.}$$

(*b*) South Wall.

Moment stability $= 37\,000 \times \frac{11.65}{12} = 35\,921$ ft.-lbs.

Moment overturning $= P \times 8.66$

$$P = \frac{35\,921}{8.66} = 4\,148 \text{ lbs.}$$

$$p = 4\,148 \times \frac{1}{92.6} = 44.8 \text{ lbs. per square foot.}$$

Wall and Floor Overturned Together.

The equations will assume their simplest forms if all forces are replaced by their equivalents acting on the line of the top of the walls.

This will involve:

First.—Computing the stability of each wall due to its own weight and the weight of the floor resting upon it, and finding the equivalent horizontal reaction at the top of the wall.

Second.—Computing the total wind forces acting on all exposed surfaces, and finding an equivalent force concentrated on the line of the top of the wall.

Equating these quantities will give the result sought.

As the area of the south wall can be acted on by only a part of the wind which passes through the openings in the north wall, the effective pressure must be reduced by an appreciable but uncertain quantity. The coefficient of reduction of 0.8, commonly used in computing the wind pressure on leeward trusses of bridges, has been used in this case. As the actual shelter is probably more than that, the use of this coefficient will underestimate the pressure and give a final result too small.

The values for center and end panels are separately computed, since the dead load of floor coming on the wall is different in each case.

Let p = pressure of the wind per square foot.

P = equivalent force of total wind pressure acting at top of wall.

F_n = reaction at top of north wall equivalent to its total resistance.

F_s = reaction at top of south wall equivalent to its total resistance.

$F = F_n \times F_s$.

Computations for Center Panel.

Stability of the Walls.

(*a*) North wall. Weight of wall, $21\,100 \times \frac{16.1}{12} = 28\,309$ ft.-lbs.

" floor, $12\,200 \times \frac{14.5}{12} = 14\,741$ "

43 050

$$F_n = 43\ 050 \times \frac{1}{13.5} = 3\ 188 \text{ lbs.}$$

(*b*) South wall. Weight of wall, $37\ 000 \times \frac{11.65}{12} = 35\ 921$ ft.-lbs.

$$\text{" floor, } 12\ 200 \times \frac{14.5}{12} = 14\ 741 \text{ "}$$

$$F_s = 50\ 662 \times \frac{1}{17.75} = 2\ 854 \text{ lbs.}$$

$$F = F_n + F_s = 3\ 188 + 2\ 854 = 6\ 042 \ldots\ldots\ldots\ldots (1)$$

Force of the Wind.

$$\begin{array}{llll} \text{Against north wall,} & 56.0 \times \frac{8.68}{13.5} & \times p = & 36.0\ p \\ \text{" south "} & 92.6 \times \frac{8.66}{17.75} & \times p \times \frac{8}{10} & = 35.6\ p \\ \text{" floor} & 21.5 & \times p & = 21.5\ p \\ \hline & & & 93.1\ p \end{array}$$

$$P = 93.1\ p \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

For equilibrium (1) = (2); $6\ 042 = 93.1\ p$

$$p = 64.9 \text{ lbs. per square foot.}$$

End Panels.

For the end panels the only difference lies in the weight of the floor resting on walls, which is 5 600 lbs. in place of 12 200 lbs. per panel. Making this change, the above equations will give the value $p = 52.7$ lbs. per square foot.

If the decking be assumed to act as a horizontal girder distributing the forces uniformly, then the average for the fourteen end and seven center panels becomes 56.7 lbs. per square foot.

The amount of material actually moved by the wind was 580 tons of masonry and 280 tons of flooring and girders, a total of 860 tons.

The preceding values, 58.2 lbs. per square foot, on the north wall acting alone, or from 52.7 lbs. to 64.9 lbs. per square foot for the entire structure acting as a unit, are the static pressures which, if exerted, will just put the material on a balance if it were standing alone. Considering that some additional concentration of force was necessary at each end to tear the material loose from the rest of the structure, and also some additional force was necessary to overcome the inertia of the total mass and set it in motion, it is fair to assume that the total pressure exerted must have been at least 60 lbs. per square foot.

The masonry of the north wall fell over on the tracks. Four of the heavy girders and some planking remained on the track floor. The masonry of the south wall and most of the iron work was lying on the ground within 75 ft. of the structure. The timber of the floor was scattered along the river front for a distance of 400 ft. The construction of the floor would naturally cause it to hold together in sections of about 17 x 18 ft. that would float on the wind some distance and carry the girders with them till the fastenings broke. One of the heavy girders was carried a distance of 120 ft. from its original position, and a section of the iron handrailing was found about 1 300 ft. from the bridge.

In addition to the damage to the east arcade, a section of the timber floor 150 ft. long on the center span of the bridge was torn up and carried away by the wind. The construction was the same as for the floor over the arcade.

These facts and figures show that at the center of the bridge for a distance of 150 ft. the wind must have exerted a lifting pressure of over 43 lbs. per square foot; that at the east end of the bridge the wind must have exerted a force equivalent to a uniform static pressure of at least 60 lbs. per square foot over an area at least 180 ft. long by 18 ft. high.

It is more probable, however, that the area of destructive pressure was more than 18 ft. high, and that the pressure was not uniform, but a maximum near the center and less at the sides. The disturbance of the bridge floor and destruction at the east tower would indicate a width of about 300 ft.

Brick Chimney.—The power plant of the Union Depot Electric Railway Company is located near the southwestern part of the area of maximum destruction shown on the map, Fig. 1. The effects of the storm at this place are indicative both of the extreme intensity of the wind pressure and of the sharp variations in this intensity in short distances.

Fig. 1, Plate III, is engraved from a photograph looking northeast over the carsheds toward the chimney.

The chimney fell over toward the north on the engine and dynamo-house, cutting it into two sections. The part toward the east was blown down and totally wrecked by the wind; the section on the west was almost entirely uninjured. The boiler-house was unroofed and its walls partly destroyed; the carsheds were completely wrecked,

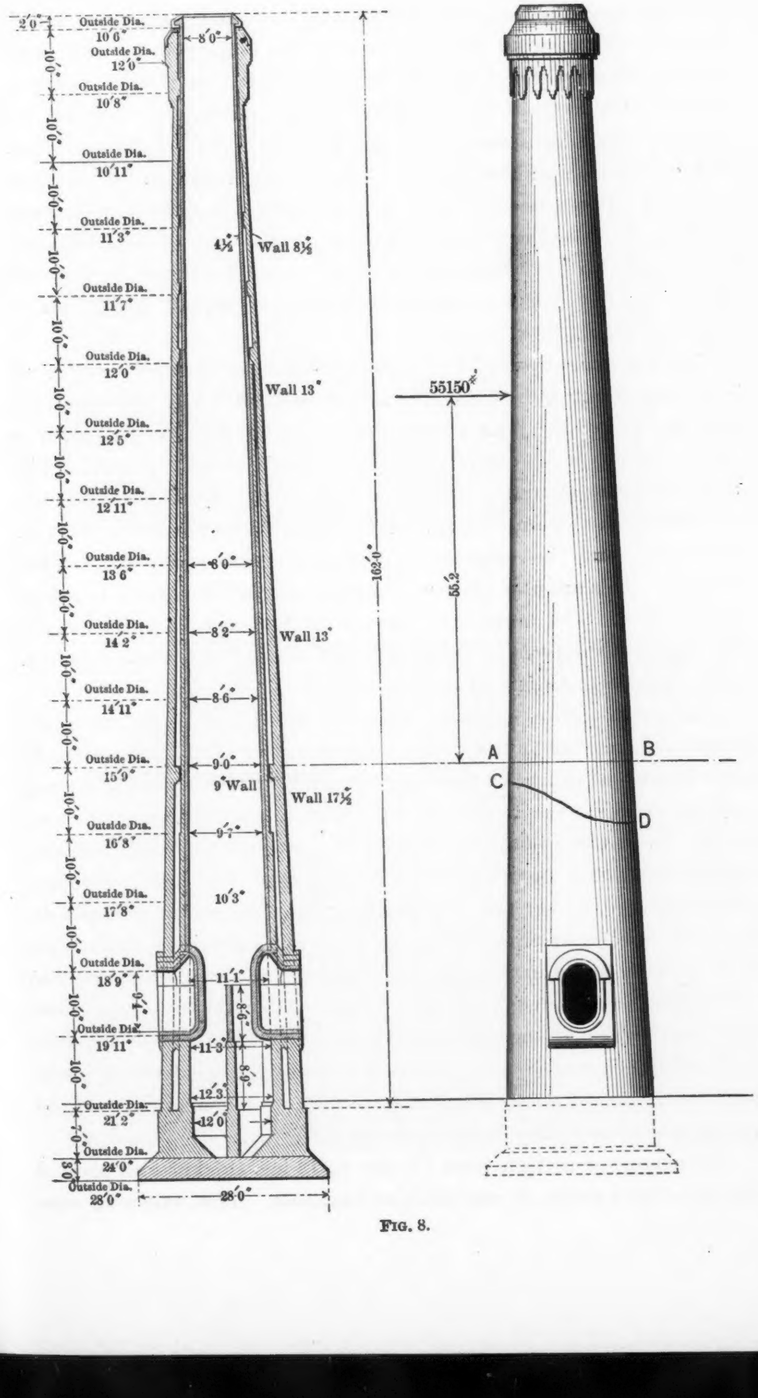
2'0"
Outside Dia. 10'6"
Outside Dia. 12'0"
8'0"
Outside Dia. 10'8"
Outside Dia. 10'11"
Outside Dia. 11'3"
4½
Wall 8½
Outside Dia. 11'7"
Outside Dia. 12'0"
Wall 13"
Outside Dia. 12'5"
Outside Dia. 12'11"
Outside Dia. 13'6"
8'0"
Outside Dia. 14'2"
8'2"
Wall 13"
Outside Dia. 14'11"
8'6"
Outside Dia. 15'9"
9'0"
9" Wall
Wall 17½
Outside Dia. 16'8"
9'7"
Outside Dia. 17'8"
10'3"
Outside Dia. 18'9"
11'1"
Outside Dia. 19'11"
11'3"
Outside Dia. 21'2"
12'3"
12'0"
Outside Dia. 24'0"
Outside Dia. 28'0"
28'0"
10'0"
7'0"
3'0"
162'0"
55150#
55.2
A
B
C
D

FIG. 8.

while the machine-shop was but slightly damaged. All these buildings were of the usual type of construction employed for such purposes, consisting merely of side walls and roof carried on posts or trusses. But a small part of the pressure exerted to overturn the chimney would have completely demolished every one of the buildings. The construction of the chimney is shown with details and dimensions in Fig. 8. It consisted of an outer shell built of selected, hard-burned dark red brick laid in a mortar of equal proportions of one part Portland cement to two parts sand, and one part lime to two parts sand. The bricks were laid with push-joints under inspection, and all joints were well filled.

The inner core was built of a ring of 4½-in. fireclay brick, reinforced in the lower section by a ring of hard-burned red brick. The firebrick were laid in fireclay. Each shell was finished at the top by a cast-iron cap 2 ft. deep, of ½-in. metal, secured to the brickwork by bolts. The inner shell was separated from the outer by a varying distance; the dimensions on the drawing give this distance as a minimum of 2 ins. at the top, and the same 50 ft. below the top where the section changes. This annular space would probably vary somewhat in actual construction. The inner shell was stayed by brackets built into the outer shell at intervals of 10 ft. There were six of these brackets on a level, each having a face of about 8 x 8 ins.

The upper section of this chimney, about 110 ft. high, was overturned by the wind. The portion left standing varied from 40 to 47 ft. in height, as shown by the line *C D*. With the exception of several vertical cracks it was in such good condition that after taking down about 5 ft. of the brickwork, the chimney was rebuilt on the remaining section. The cast-iron shells forming the caps of the chimney were shattered by the fall, and the fragments lay in different places; they were probably blown about by the wind. Some of the largest sections were found in a cellar just inside the line of the building and 100 ft. from the chimney. Most of the débris fell in the engine-room between the base of the chimney and the street, and part of it to the south of the chimney. The lightning-rod was thrown forward across the street. Almost immediately after the fall of the chimney, the wind veered around and blew in the opposite direction.

The change in section from 17½ ins. to 13 ins. thickness at level *A B* makes this a point of comparative weakness. This, taken in con-

FIG. 1.

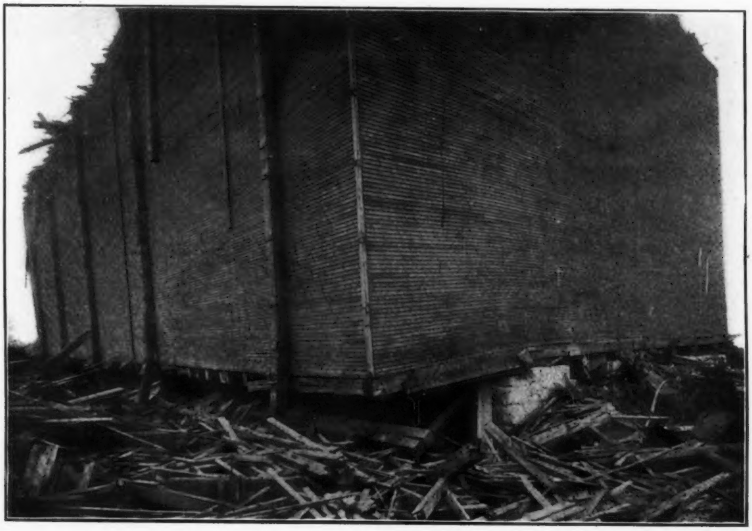

FIG. 2.

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nection with all other facts, renders it probable that the chimney failed by the crushing of the brick masonry on the extreme leeward side just above the section *A B*, due to the concentration of pressure at that point, and overturned bodily; that the rupture of the walls shattered the brickwork for some distance, and that the shifting wind blew off the loose fragments down to the line *C D* and scattered the débris about the base.

Stability of Chimney.

The following computations have been made, as closely as possible in accord with actual conditions, to find the least force which must have been exerted by the wind to cause the failure of the chimney at the section *A B*. The assumptions made for this purpose are:

I.—That the joints can take no tension and that when the center of pressure has reached its limiting position, the joints have opened from the windward side diagonally across the base of the chimney, leaving a wedge above the line *A B*, which does not take part in the movement of the upper section.

II.—That the mortar has sufficient coherence to hold the upper section in shape till it has passed the point of equilibrium.

III.—That the weight of red brick masonry is 115 lbs. per cubic foot, and the weight of firebrick 120 lbs. per cubic foot.

IV.—That the brickwork will not fail by crushing till the pressure has reached a value of 50 to 70 tons per square foot, or about 700 to 1 000 per square inch. A wide range in value assumed for the crushing strength has little effect on the final result in this case, as will be seen hereafter.

V.—That the effective air pressure on a cylinder is 0.54 as much as on a plane surface whose area is equal to that of the diametral section of the cylinder. The valuation of this coefficient is the most uncertain element in the problem. It is variously given from 0.5 to 0.6, a range of nearly 20 per cent. In designing new work it is sufficient to assume a safe value, but in the present instance it is essential to have as nearly the true value of this coefficient as possible. The value of 0.54 has been taken as representing nearly a mean between the latest values determined experimentally by entirely different methods. Professor Kernot by experimenting with models placed on a delicate movable carriage in front of an air blast has found this value to be

0.50, while the experiments of Irminger made with hollow models placed in an air duct, by means of which the actual pressure at all points on the surface of the cylinder was determined, gives the value of this coefficient as 0.57.

Computation for Outer Shell.

Let p = pressure of wind per square foot.

F = total force of the wind against section overturned.

Y = distance of center gravity of exposed surface above $A\ B$ = 55.2 ft.

W = total weight of section of chimney overturned.

x = lever arm of weight W = distance from center of gravity of W to center of pressure.

Overturning Force of the Wind.

Total area of diametral plane above $A\ B$	1 386 sq. ft.
Average area of wedge at base	93 " "
Net area	1 293 " "

Effective area = 1 293 sq. ft. × 0.54 = 698 sq. ft.

then $F = 698\ p$.

Moment overturning = $y\ F = 55.2\ F$ ....(1)

Resistance of Chimney.

Total brickwork above $A\ B$ = 3 871 cu. ft. at 115 lbs. = ...	445 165 lbs.	
Deduct wedge at base 187 cu. ft. at 115 lbs. =	21 500 "	
Net weight of brickwork		423 665 lbs.
Cast-iron cap and fastenings		3 335 "
Total weight overturned = W		427 000 "

Distance center chimney to center gravity of wedge at base = 4 ft.

Distance center chimney to center gravity of $W = \frac{21\ 500}{427\ 000} \times 4.0 =$ 0.2 ft.

Assuming center of pressure to fall at center of outer shell, or $6\frac{1}{2}$ ins. back from face of chimney, gives 7.33 ft. from center of chimney to center of pressure.

Then x = 7.33 ft. − 0.2 ft. = 7.13 ft.

Moment resistance $= Wx = 427\ 000 \times 7.13 = 3\ 044\ 500$ ft.-lbs. (2)

For equilibrium (1) = (2) $\quad 55.2\ F = 3\ 044\ 500.$

$$F = 55\ 150 \text{ lbs.}$$

$$p = \frac{F}{698} = 79.0 \text{ lbs. per square foot.}$$

The deduction of the wedge at the base makes a difference of 6 lbs. in the result; that is, if the entire chimney above $A\ B$ is assumed to hold together and resist overturning, the value of p becomes 85 lbs. per square foot.

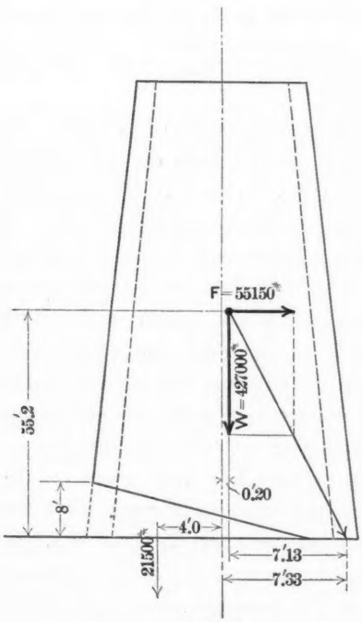

Fig. 9.

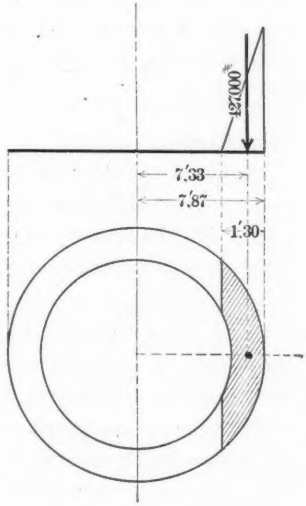

Fig. 10.

Making the customary assumption that the pressure is distributed at a uniformly varying rate, it can be graphically represented, as in Fig. 10, by a hollow wedge, the volume of which is equal to the weight W, and the base and altitude such that the center of gravity of the wedge must coincide with the position assumed for the center of pressure of the load W, in this case $6\frac{1}{2}$ ins. from the edge of the wall.

The direct mathematical formulas for the hollow wedge are quite intricate and difficult of application, particularly for small segments.

The values given here were found by successive trials. By drawing the plan on a large scale, assuming the width of the base of the wedge, and dividing the latter into small vertical prisms, the volume and center of gravity, in terms of the pressure on the extreme edge, can be readily found by use of a slide rule, with an error of less than 1 per cent. Varying the base by successive increments, a few trials will not only give the desired results, but also show more clearly than the formulas the change in these results due to changing the assumed data. For the center of pressure assumed, 6½ ins., from the face of the wall, the wedge was found to have a base 1.3 ft. wide, and an area of 7.15 sq. ft., and the pressure on the extreme edge was found to be 2.33 times the average pressure, or $2.33 \times \frac{213.5}{7.15} = 69.5$ tons per square foot.

A small variation in the position of the center of pressure will make a great difference in the theoretical pressure on the extreme edge. If it be moved toward the center 0.1 ft., the maximum pressure becomes 53.9 tons per square foot; and if moved toward the edge of the wall 0.08 ft., the maximum pressure becomes 87.8 tons per square foot. A total variation, therefore, of only 0.18 ft. in the position of the center of pressure, and consequently of the length of the lever arm, making a difference of only 2½% in the computed wind force, will change the maximum pressure on the extreme edge of the brickwork from 53.9 tons to 87.8 tons per square foot, a variation of 62 per cent. The limit assumed in this particular case for the crushing resistance of the brickwork can therefore have but little effect on the final estimated wind pressure. It is moreover improbable that the pressure will vary from 69 tons to zero in the short distance of 1.3 ft. For such an extreme weight on a small area a slight compression of the mortar will quickly redistribute the pressure more uniformly, giving a much lower unit pressure than found by the formula.

The total weight of the inner shell or core above the line *A B* is 107½ tons. A computation similar to the preceding one shows that this weight will be held in equilibrium by an external force of 17 600 lbs. applied 56.1 ft. above *A B*. This is equivalent to a uniform pressure of 24.8 lbs. per square foot over the effective surface exposed to the wind.

The value to be placed on the core in estimating the ultimate strength of the entire chimney is uncertain. Although in the design

of a new chimney entire dependence should be placed on the outer shell, it is evident that the latter cannot be actually overturned unless the core is taken with it. The extent to which the possible resistance of the core will be effective at the moment when the outer shell is brought to the point of failure will depend upon the efficiency of the brackets, the distance between the shells at the top, and the relative stiffness of each shell.

The deflection of a brick chimney under extreme lateral forces cannot be definitely computed. It will depend upon the elasticity of brick and mortar under compression on the leeward side, and upon the opening in the joints on the windward side. As any movement in the joints near the line $A\,B$ will cause a lateral motion of seven times that amount at the top, it is quite probable that the outer shell will be brought to a bearing against the core in case the brackets do not prove efficient. From such approximate computation of the stiffness of the shells as the case will admit, the author assumes that at least one-fourth to one-half of the possible resistance of the core must be taken into account, or a pressure of from 6 lbs. to 12 lbs. per square foot must be added to the resistance of the outer shell. This gives a total of 85 lbs. to 91 lbs. per square foot necessary to hold the chimney just at the point of equilibrium. To this must be added some additional pressure to overcome the inertia of the mass and set it in motion.

The preceding data and computations show that the wind must have exerted in this locality a force equivalent to a static pressure in excess of 85 to 91 lbs. per square foot over an area of at least 14 ft. wide by 110 ft. high. The total material moved was 321 tons.

It is probable that the pressure was not uniform, but greater near the top. It is also possible that the chimney was overturned either by successive gusts of wind whose period of recurrence was timed to the oscillations of the chimney or by one sudden and intense blast. In the former case the actual pressure of the wind might be much less, in the latter it would be more than that given by the above figures.

The Valley Grain Elevator.—The largest and heaviest single object that was moved by the wind is a grain elevator standing on the east shore of the Mississippi River on about the south line of the path of the storm. This building is of the usual type of elevator construction and is shown in outline and general dimensions in Fig. 11. The heavy

lines indicate the present position of the wreck as seen in Fig. 2, Plate III, and Fig. 1, Plate IV; the light lines indicate its position before the storm. The upper part of the building or cupola was about 50 ft. wide by 58 ft. high, and extended the full length of the building. It consisted of a framework of timbers supporting a series of partial floors on which were located the machinery, bins, scales, distributing chutes, etc., which constitute the operating mechanism of a grain

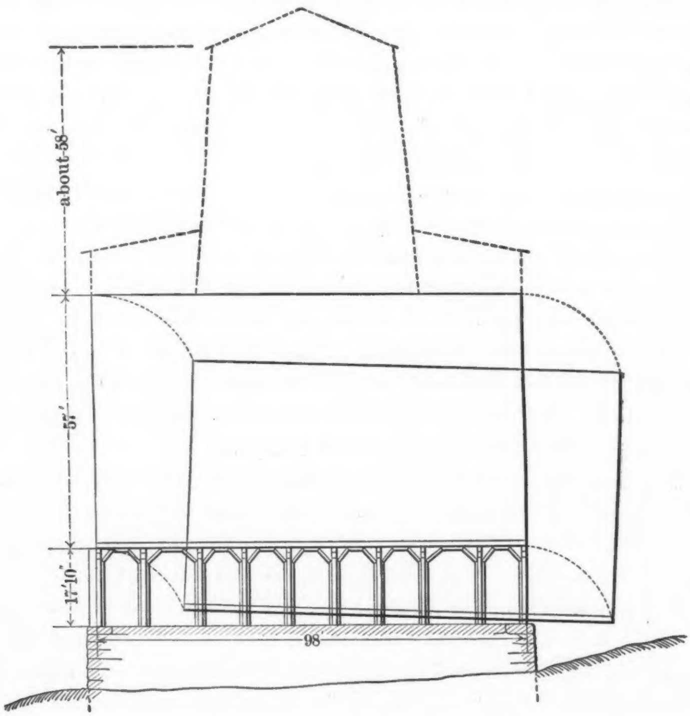

FIG. 11.

elevator. The binwork or lower section of the building proper is 57 ft. high, 98 ft. wide, and about 200 ft. long. It is divided into bins about 11 ft. square by a series of ten longitudinal and nineteen cross-walls built up of 10-in., 8-in. and 6-in. planks, laid flat on each other and securely spiked together. These walls form in effect a series of deep wooden girders intersecting and interlocking into each other and forming a huge box of great strength and rigidity. Im-

mediately underneath each outer and cross-wall is a 12 × 16-in. timber sill, which is fastened to and forms a part of the wall above it. The sills and the entire structure are carried by the "twin girders," a series of double timbers, a 12 × 14-in. placed on top of a 14 × 14-in., running under each longitudinal wall and supported in turn by 12 × 14-in. vertical posts, one under each point of intersection of these main timbers. The posts rest on a substantial foundation of stone walls and piers. The details of posts and bracing are shown in

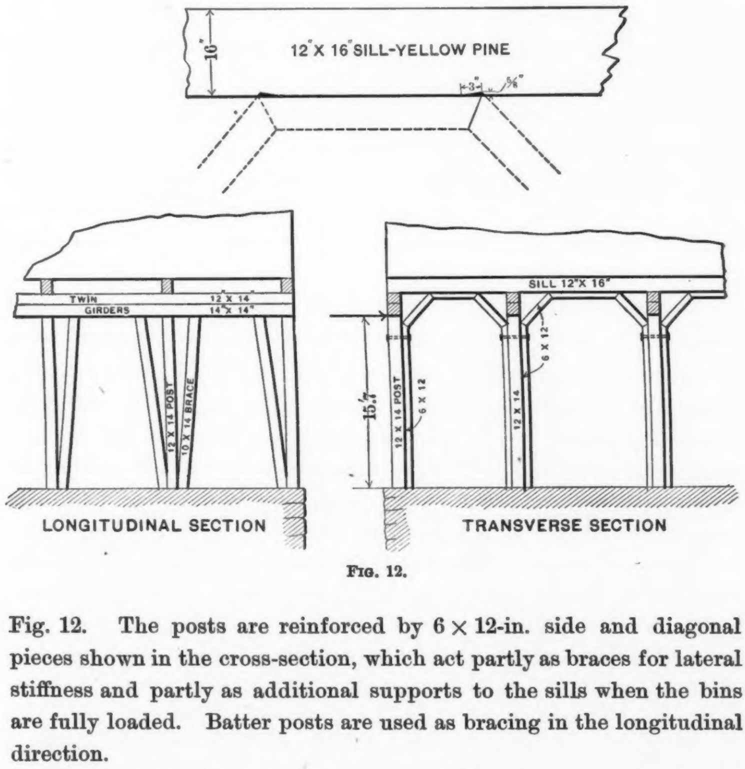

Fig. 12.

Fig. 12. The posts are reinforced by 6 × 12-in. side and diagonal pieces shown in the cross-section, which act partly as braces for lateral stiffness and partly as additional supports to the sills when the bins are fully loaded. Batter posts are used as bracing in the longitudinal direction.

The wind blowing from the west pushed over the entire structure with its supports and tore off and overturned the framing and contents of the cupola down to the level of the bin floor. The building was moved towards the east 19½ ft. at the south end, and 18½ at the north end, and towards the north about 1 ft. As the distance from the

bottom of the posts to the sill was 17 ft. 10 ins., the building moved sideways but little more than the distance it fell, the path of motion probably being on nearly the arc of a circle, having the height of support as its radius. The binwork, somewhat racked and out of plumb, is resting on the foundation and overhangs the east wall, as shown in Fig. 2, Plate III, from a photograph taken from the northeast corner Fig. 1, Plate IV, is a view taken from the southwest. The face of the building was originally above the stone foundation wall and nearly on line with it. The timbers showing above the wall at the left-hand end of the plate formed the outer row of supports.

This elevator was built in 1883, and no records showing details of construction were accessible. The dimensions of the binwork and supports were obtained by measurements taken from the wreck; the cupola was assumed to be the same as that on other elevators of similar construction and dimensions. The building was empty at the time of the storm. The estimated dead weight of the structure is about 3 500 tons, with a possible error of several hundred tons either way.

The uncertainty as to the exact height of the cupola, and the exact weight of the total building, and particularly the indeterminate value of the bracing, renders a definite estimate of the wind pressure impossible. The bearings of the sills on the longitudinal girders, and of the latter on the posts, were unsecured in any way except by the friction due to the weight. The 6 x 12-in. uprights were fastened to the post by a single bolt, and the diagonal pieces were toe-nailed to hold them in place.

The maximum resistance due to the weight alone will be brought into action after some movement, causing some inclination of the posts, has taken place and has thrown the bearing to the leeward edge at the base and towards the windward edge at the top of the post, giving an effective lever arm of possibly 10 ins. Then

$$\text{Moment of resistance} = 7\,000\,000 \times \frac{10}{12} = 5\,833\,000 \text{ ft.-lbs.}$$

$$\text{“ “ overturning} = F \times 15.7.$$

$$\text{Total wind force} = F = \frac{5\,833\,000}{15.7} = 371\,500 \text{ lbs.}$$

$$\text{Exposed area} = 115 \times 200 = 23\,000 \text{ sq. ft.}$$

$$\text{Pressure per square foot} = \frac{371\,600}{23\,000} = 16.1 \text{ lbs.}$$

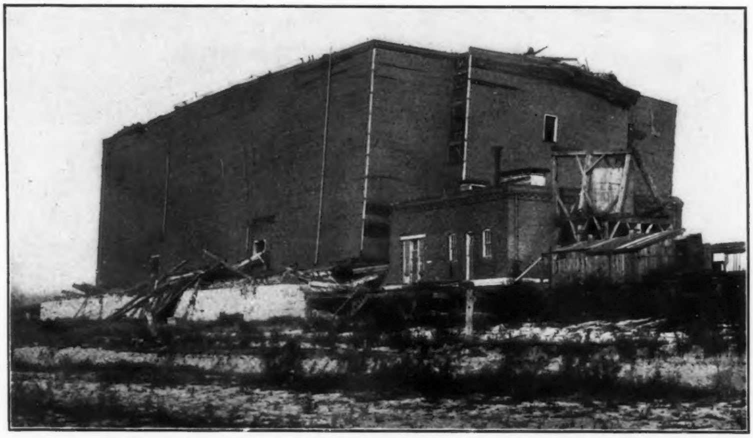

FIG. 1.

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The evidence of the resistance offered by the bracing is seen in the crushing of the fibers of the yellow pine sills. The diagonal pieces crowding against each edge of the upper horizontal timbers have in many instances crushed the latter into the underside of the girders, leaving an indentation triangular in shape, $\frac{5}{8}$ in. deep, as a maximum, as shown in Fig. 12. The exact value of this resistance is indeterminate, but it would materially increase the wind pressure necessary to move the building, making it probably 20 lbs. or more to the square foot.

It would seem reasonable to conclude that in this case the wind must have exerted a force equivalent to a static pressure at least 16 lbs. to 20 lbs. or more per square foot over an area at least 200 ft. long by 110 ft. high. It is probable, however, that the pressure was not uniform, but was double this amount or more against the upper part of the building. The slight movement of the building toward the north, and the greater lateral displacement at the south, end would indicate a diagonal direction of the wind and a heavier pressure near the latter end, while the fact that the brick building used as an engine-room standing at the south end was entirely uninjured by the wind would indicate that the pressure was varying and greatest near the top.

The grain elevators located along the river front have all suffered more or less, owing to their height and exposed condition. In four other buildings the cupolas were overturned and completely wrecked. One of these buildings showed indications of racking, though partially loaded with grain at the time. In another elevator, a building 350 ft. long and of the same general construction as that described, except that it was braced more effectively with the batter posts in the transverse section, there were evidences that the building had been partially moved out of place and settled back again. The plumb posts on the extreme leeward side were moved outward at the bottom for half the length of the building, the displacement being 11 ins. at about the quarter point and varying to nothing at the middle and end of the building. On the windward side many of the batter posts had fallen out of place and were found on the floor. Several sections of the cupola at the end were torn away. The great length and stiffness of this building probably prevented it being pushed over on its supports. The equivalent pressure was at least 20 lbs. for a length of 100 ft. of building. This elevator is parallel to and north of the bridge, and the wind was from the north or the same direction as at the bridge.

Mercantile Buildings.—The damage wrought on some of the large and substantially constructed buildings, of which there were only a few in the path of the storm, will convey some further impression of the force of the wind, even if it cannot be estimated.

A building of this type is represented in Fig. 2, Plate IV. It is 64 ft. wide by 126 ft. long and six stories high, built with heavy exterior walls and with standard mill construction on the interior. The full wall shown in the illustration faces west; the east face is similar in construction to the south front. The brickwork in the top story was 13 ins. thick in the full wall, 17 ins. in the pilasters between the windows, and was all laid in mortar of lime and Louisville cement. It was built three years ago, so that the mortar had ample time to set. The roof was constructed of a double thickness of planking with an air space filled with mineral wool, and was furnished with an extra heavy tar and gravel covering. It was carried on beams supported by 9 x 9-in. uprights, and would probably weigh about 20 to 25 lbs. per square foot.

The entire sixth-floor walls were demolished and the roof lifted and carried off by the wind, part of it falling on and crushing the one-story building immediately adjoining it on the west. The wind evidently blew into the east windows and lifted the roof, as nearly all the posts, with the cast bearing-plates still on top of them, were left standing in place; the first row can be seen in the illustration.

A second example of the damage done to a substantial building is given in Fig. 1, Plate V, which shows the south wall of the upper four stories blown out by the difference in pressure of the air on the inside and the outside of the building, the material of the walls all falling on the outside. The walls were 13 ins. thick in the fifth and sixth stories, and 18 ins. in the third and fourth stories; the pilasters which supported the floor girders were 26 ins. thick. The building was erected about eight years ago. With the exception of the parapet wall and a section of the upper story of the building, it sustained no other serious damage.

Another instance of a brick wall blown out by a difference in pressure occurred in the elevator building at one of the large brewery plants, a brick shell, constructed around the grain bins, having its walls stayed at intervals by slip anchors fastened to the sides of the wooden bins. The end wall, 13 ins. thick, 40 ft. wide, and about 75 ft.

FIG. 1.

FIG. 2.

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high, was forced out its entire height. The brickwork in this case was laid in Portland cement mortar, and was of excellent quality. The débris showed large sections of brick masonry still bonded solidly together, the wall evidently breaking through the bricks as readily as at the joint.

In Fig. 2, Plate V, is shown the framework of a group of three mercantile buildings in various stages of construction, about as they appeared on the day of the storm, the view being taken sometime previous. The buildings are four stories and basement in height, about 110 ft. wide by 250 ft. long, situated end to end in one line, and partly separated by open courts. The outer walls are of heavy brick masonry; the interior consists of a skeleton framework of cast-iron columns and steel beams. The metal-work was completed, except the beams of the outer panels of the upper floors, which were necessarily omitted until the walls were brought up to the proper height. The framework of the building in the foreground, some 1 200 to 1 500 tons in weight, was completely wrecked by the storm, the view in Fig. 1, Plate VI, showing the result. The building at the extreme end had the upper two or three stories wrecked, while the frame in the center building escaped uninjured.

The floor plan of the building was of the customary design, the essential features being shown in Fig. 13. It consisted of longitudinal girders of two 15-in. I-beams fastened together with the usual cast separators. The trimming joists were 15-in. I-beams, and the floor beams were 12-in. I-beams, coped and framed into the girders so as to be flush on top. In the outer panels a 15-in. I-tail trimmer, adjacent to the wall and framed into the 15-in. trimming joists opposite the column connections, carried the headers, which otherwise would have rested directly over the windows, in the brick walls. All connections were made with standard 6 x 6 x $\frac{7}{16}$-in. connecting angles, with five holes in each leg, which came shop-riveted to the end of the 12-in. floor beams. The field connections to the girders at all interior points were necessarily made with long bolts; all connections in the outer panels adjacent to the wall were riveted, bolts and rivets being $\frac{3}{4}$ in. diameter. The cast columns were fastened to each other by four $\frac{3}{4}$-in. bolts through heavy flange lugs at each joint, the girders and beams being supported on brackets and bolted through their webs to vertical lugs cast on the columns.

The details of the wreckage, representing, as they do, a drop test of full-size members on an unusually large scale, present some points of interest in regard to the behavior of the material under extreme conditions that have a direct application to some details of customary practice in the steel framework of high buildings, and are therefore given at some length.

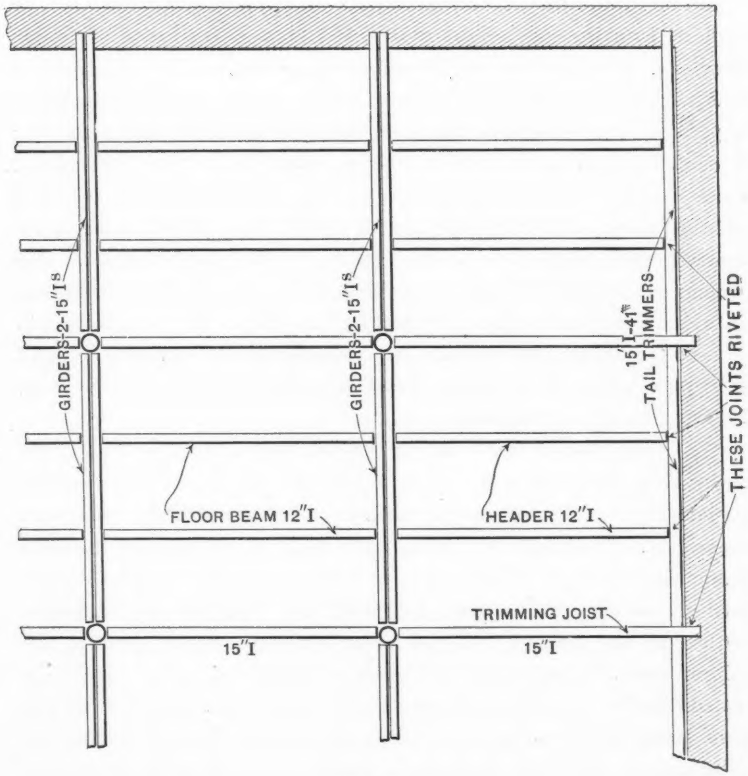

FIG. 13.

The roof beams and girders which fell on top of the wreck were subjected to no shock except that due to their own weight, and were nearly all in good condition. The floor beams on the various floors, being caught between falling columns and girders, were badly bent and twisted. The author was informed that a number of the beams had the flanges cracked, and he personally saw several beams broken off

PLATE VI.
PAPERS AM. SOC. C. E.
JANUARY, 1897.
BAIER ON TORNADOES.

FIG. 1.

FIG. 2.

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at the ends, the fracture beginning at the end of the coped top flange and extending diagonally across the web and bottom flange, as shown in Fig. 14. A common method of failure is shown in Fig. 15; the flange of the beam, probably due to a blow coming on one edge, is doubled almost into the line of the web, and both are deflected sideways. A careful inspection of numerous cases of extreme distortion similar to the last failed to show any cracks in the metal.

A striking fact noted throughout the work of clearing the wreck was the superiority of riveted over bolted connections when the joints are subjected to strains from bending, twisting or wrenching, such as they might be called on to resist in the column connections of a high building. In most of the roof beam connections, and in some of the joints in the floor where the beams maintained their relative position, the bolts were good, but wherever the beams were twisted out of

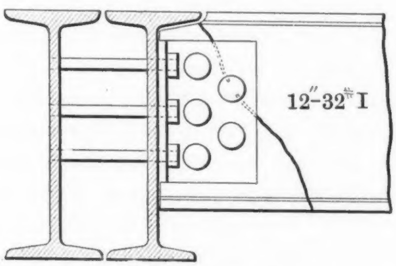


FIG. 14

FIG. 15.

position, the bolts invariably failed. Fully two-thirds to three-fourths of all the bolted connections were either broken apart or so weakened that the beams could be easily pulled apart. The riveted joints, on the other hand, made a much better showing. The floor beams of the outside panels of the first and second floors were nearly all in place, and the joints riveted at the time of the storm. These beams were caught beneath the falling material of the upper floors and were dragged down against the side wall in such a way as to twist most of the beams and girders out of line and position. Although these joints were thus subjected to the severest test of any in the structure, yet in nearly every instance they hung together and required the rivets to be cut out before the wreckage could be cleared. The line of tail trimmers of the second floor can be clearly seen against the wall shown in the right-hand side of Fig. 1, Plate VI, which is a view of the wreck

taken shortly after the accident. Fig. 2, Plate VI, is a view taken during the clearing of the wreck.

At various times during the clearing of the wreck the author made a detailed examination of 49 of these joints, containing a total of 735 rivets. As on an average, at least, three rivets out of the fifteen at each joint were strained in tension, there were 149 rivets in this number that were put to a severe test. Fifteen of these rivets, or about 10% of the number, were found with the heads off or broken in the body, and seven were noticed that had been elongated on one side as much as $\frac{3}{16}$ to $\frac{1}{4}$ in. The maximum number that failed at any one joint was three, and in every instance the rivets that were broken or excessively distorted were in the inner row. In three places the material had been so violently wrenched that both connecting angles were torn apart at the root of the angle, and the beams pulled entirely away from each other, and in two other instances one of the angles was torn apart; otherwise the girders hung together by the riveted joints in continuous sections. In no instance was a connecting angle torn entirely off from any beam to which it was riveted.

Plate VII shows some of the distorted rivets, a broken bolt, which is a characteristic specimen, and half of one of the connecting angles that was torn apart. The last was still attached to the web of the beam by the three rivets, about in the position shown in the illustration. The rivets were still sound and were cut out in clearing the wreck. Evidently the angle, when pulled away from the beam, split at the rivet holes and pulled over the rivet heads, which were somewhat eccentric and did not have their full grip, acting much like soft paper torn from a board to which it is nailed.

At most of the joints the beams were bent around toward the girder to various angles, in some places as small as 30 degrees. Fig. 16 is a sketch of a joint at the connection of a 12-in. header to the 15-in. tail trimmer, made from measurements taken on the center line of the 15-in. I-beam, and is characteristic of the condition of a great many of these connections.

The bottom flange of the beam, being very stiff laterally, maintained its line, but the web, which was already weakened by coping of the top flange, was split away from the bottom flange and bent sharply. The connecting angles were distorted as shown, and the web of the 15-in. I-beams 0.41 in. thick were drawn as much as $\frac{1}{2}$ in. out of line. The

rivets in these connections were all sound and had to be cut out. The rivet holes in the distorted webs of the beams generally showed cracks at the edges on the convex side.

It is of course impossible to deduce any quantitative results from a test of material made under such conditions, but the number of pieces, the diversity of conditions and the general uniformity of results furnish some definite average values as to the relative strength of a few structural details when brought to the point of failure.

Considered in reference to the particular instance and type of structure in which they were observed, these facts have no application

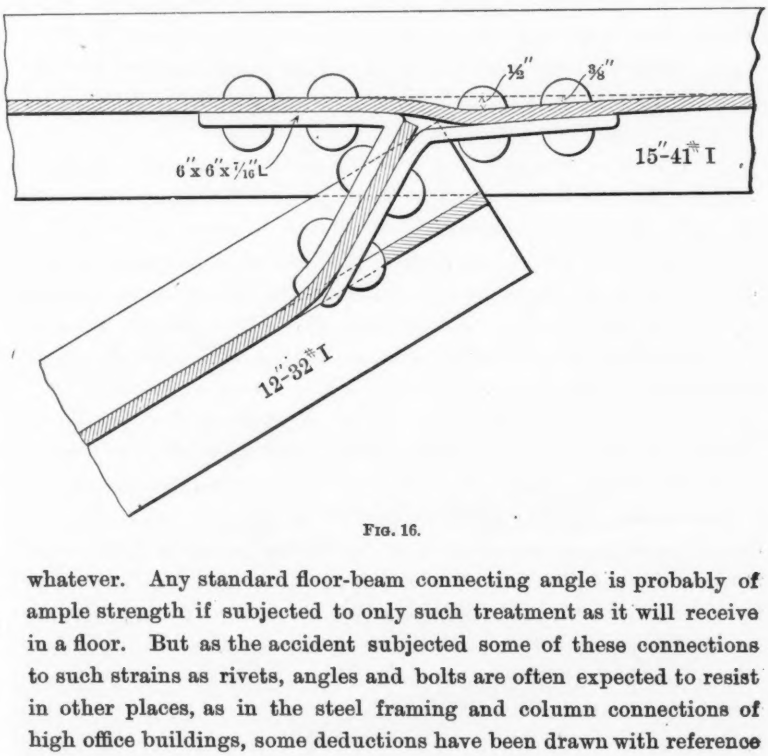


FIG. 16.

whatever. Any standard floor-beam connecting angle is probably of ample strength if subjected to only such treatment as it will receive in a floor. But as the accident subjected some of these connections to such strains as rivets, angles and bolts are often expected to resist in other places, as in the steel framing and column connections of high office buildings, some deductions have been drawn with reference to their application where they may seem appropriate.

The facts observed show conclusively:

1. That for any twisting, wrenching or bending strain a ¾-in. rivet is far superior to the ordinary ¾-in. bolt.

2. That the tension value of three ¾-in. steel rivets is sufficient to distort the web of a 15-in. 41-lb. I-beam ½ in. out of line without failure of the rivets, and is also far in excess of the bending resistance of the metal in a $\frac{7}{16}$-in. connecting angle.

3. That a tension strain transmitted across the root of an angle from one leg to the other will cause a bending and a distortion of the angle and bring an eccentric tension strain on the nearest line of bolts or rivets, and that under such action, in an angle as light as $\frac{7}{16}$ in., the second row of rivets will not act till the first row has failed.

4. That an eccentric tension strain will readily cause a bolt to fail by bending or breaking in the thread, while the steel rivet will stand considerable distortion without failure.

5. That well-riveted joints in steelwork will stand, even under jar and shock, an excessive amount of abuse and distortion before actually separating into individual pieces.

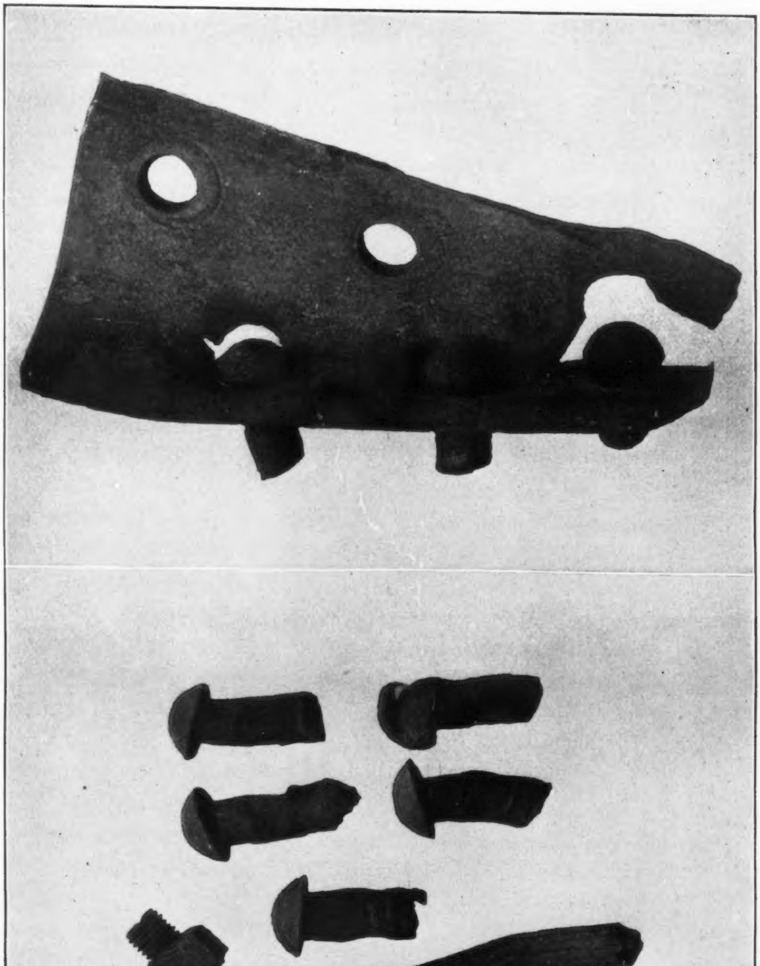
These facts are entirely in accord with a theoretical analysis and are recorded here because they are facts, and because they apply so directly to what might be called some of the "units" of structural work.

The rivet in tension has always been an object of suspicion and distrust; it would seem consistent to be equally discriminating against some other details often used; notably the bolt in tension, the diaphragm plate resisting thrust or tension, and the thin connecting angle under cross-tension strain.

III.—Method of Action of the Wind and Theory of Tornadoes.

While a measure of the force of the wind is of the first consideration to the engineer, the application of this force, and the more immediate influences and causes governing it, follow closely in point of interest. The volume of destruction and the many apparent vagaries of the destructive agent will justify a brief résumé of such experimental knowledge as seems to have a direct bearing on the subject, particularly as some of the results obtained from laboratory tests on models seem to find confirmation in the full-size test applied by Nature on the buildings.

Wind has been defined as "merely the flowing away of air from where there is a surplus of it to where there is a deficiency." All winds from the lightest breeze to the most disastrous hurricane take their rise in irregularities in the distribution of the atmospheric pressure,



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whether these irregularities originate in the temperature or aqueous vapor. The velocity of the wind, and, consequently, the force exerted by it, must depend largely on the difference in the atmospheric pressure at any two points and the distance between them.

The relation between the flow of air and the pressure it exerts on surfaces exposed to its action is expressed by the generally accepted formula $P = c\,v^2$ were P is pressure in pounds per square foot, v is the velocity in miles per hours, and c is a constant, affected by temperature and barometric pressure, which must be determined by experiment. Notwithstanding the many careful and elaborate experiments * made to determine or verify this general formula, the value assigned to the constant c covers a wide range. The United States Weather Bureau has adopted the value $c = 0.0040$, making the formula $P = 0.004\,v^2$. A generally accepted value is 0.005, while the experiments of Whipple and Dines in England give the value 0.0029, a variation of nearly 25% either way.

As the values of this constant have nearly all been determined from velocities not over 60 to 70 miles per hour, and as it is, moreover, the general opinion of nearly all investigators that the law of pressure-velocity variations found by experiment with whirling machines is correct only within the range of speeds covered by those experiments, the values deduced from the lower velocities not being safely applicable to higher velocities, it follows that any formula must be accepted as giving only a very broad average result for velocities up to about 70 miles per hour, and only the most general approximation for velocities much higher.

Any formula expressing the relation between the pressure and velocity of the wind must be based on the assumption that the air flows in a uniform current. All experiments in the open air show that the actual conditions are far different, and the great diversity in the observed results is due largely to the continued and rapid fluctuations in the velocity of the winds. The extent to which this gusty nature is characteristic of the wind at all times and the allowance to be made for it when using the formula to convert wind velocity into pressure, appears more clearly in the detailed results of the experiments made by Professor C. F. Marvin on Mount Washington, to determine the

* See "Wind Pressures in Engineering Construction," by W. H. Bixby, *Engineering News*, March 14th, 1895.

value of the constant in the formula now in use by the United States Weather Bureau.

The pressure exerted by the wind on plates respectively 4 sq. ft. and 9 sq. ft. in area were carefully measured by a delicate self-recording mechanism for velocities ranging from 7 miles to 48.5 miles per hour. The velocity of the wind was measured by the standard Robinson anemometer placed about 4 ft. higher than the center of the pressure plate and recorded by electrical contacts every fifty revolutions of the cups, equal to one-tenth of a mile of wind movement.

The following statement of results is taken verbatim from the report of Professor Marvin: *

"The records of the pressure and velocity of the wind were, therefore, automatically and simultaneously recorded on the same sheet of paper. The curve of pressures, if it can be called a curve, presents, in spite of the comparatively rapid rate of rotation of the register, a very irregular appearance indeed. The oscillations do not, except for occasional instants, correspond to harmonic vibrations of the spring and pressure plate as a vibratory system, but are actual and real changes in wind pressure. The magnitude of these variations is, itself, very irregular, but it may be stated to be approximately as much as 35% of the mean pressure. There is, in addition to these very rapid variations in the pressure which take place inside of a second or two of time, other variations which go through their irregular changes in from a few to several minutes' time.

"These circumstances led to the following method of reducing the observations. The traces on the record sheets were divided into portions representing, generally, four or five minutes of time, and during which the conditions were, to some extent, constant. The traces of the pressure were all gone over by hand and a red-ink line drawn through the pencil mark in such a manner as to get a mean curve. In this only those variations which were of such short period that the pencil marks were too close together to distinguish were evened up. All changes of larger periods were followed accurately. The next step consisted in carefully measuring the area of each subdivision, including, of course, everything between the red-ink trace and the line of zero pressure. This measurement was very satisfactorily made by a small planimeter. The mean pressure is now quite accurately found by dividing the area by the length of the base of the diagram. The mean wind velocity corresponding to the same portion of the sheet is determined from the simultaneous record of the anemometer. The large number of observations obtained in this way have been grouped in sets corresponding to the velocity, and a final mean determined.

* Annual Report, Chief Signal Officer, 1890. Report upon Wind Pressures.

"For engineering purposes this formula gives very closely, I think, the actual pressures corresponding to velocities computed by the logarithmic formula, as applied to the Robinson anemometer, and this is the instrument almost universally used in measuring wind movements. Where the Robinson anemometer, having its dials graduated to read miles, is used, the observed velocity can be easily reduced to the true volocity.*

"In estimating the strains to which engineering structures may be subjected by the winds, the maximum pressures are, of course, the most important. The above formula gives a mean pressure corresponding to a mean wind velocity. It is important to note that momentary pressures as much as 35% in excess of the above mean pressure may continually occur and recur. If their rate of occurrence be at all synchronous with a natural time of vibration of the structure or any part thereof, remarkable effects may follow."

A further and more definite evidence of the irregular and gusty action of the winds is found in the experiments of Professor S. P. Langley,† comparing the ordinary records of velocity with the actual motion of the winds. The velocities of the wind, as recorded by the United States Weather Bureau, are measured by the standard Robinson cup anemometer, which in practice is made to register only the completion of the passage of each mile of wind. As the instruments are necessarily made of a strength and weight adapted to continuous and general service, their momentum renders the motion of the cups more uniform than that of the wind. The records, therefore, give about the average velocity of each mile of wind, but do not show the intermediate variations due to sudden gusts. To determine the rate and extent of these fluctuations in velocity, Professor Langley conducted a series of experiments with a standard anemometer recording every five revolutions, and with a special anemometer made so sensitive that it would start and stop almost instantaneously with the wind. This latter instrument was made of half the usual diameter, and fitted with paper cones in place of metal cups, the weight and moment of inertia being less than 1% of that of the standard anemometer. Electrical contacts were made every half revolution recording the velocities several times a second. Observations were taken at Allegheny City and at Washington on high points free from irregularities due to trees, houses or inequalities of the ground on different days, and in

* See table in Appendix.

† "The Internal Work of the Wind." S. P. Langley, Smithsonian Contributions to Knowledge, No. 884.

light to moderately high winds ranging in velocity from 9 to 36 miles per hour. The experiments show clearly that even the ordinary and comparatively uniform wind is but a succession of gusts of varying intensity. The results of the observations are shown graphically on a series of diagrams, one of which selected as a characteristic example is reproduced in Fig. 17. The diagram is an actual record for ten minutes showing the rapid changes that take place in the velocity of the wind.

The observed points represent the wind's velocities as computed from intervals between each successive contact, and for convenience are connected by straight lines.

The heavy line through *A B C* represents the ordinary record of the wind's velocity as obtained from a standard Robinson anemometer registering every mile, during the observations recording the passage of 2 miles of wind in about 5½ minutes of time. The velocity which was at the beginning nearly 23 miles per hour fell during the course of the first mile to 20 miles per hour and rose at the end of the second mile to 27 miles per hour.

The records of the same wind made at every second with the specially light anemometer show that, starting with 23 miles, it rose within ten seconds to a velocity of 33 miles, and within ten seconds more fell to its initial speed; it then rose within thirty seconds to a velocity of 36 miles per hour, and so on with alternate risings and fallings, at one time actually stopping—passing through eighteen notable maxima and as many notable minima, the average time of each rise or each fall being a little over ten seconds, and the average change of velocity in this time being 10 miles per hour. There were in addition almost innumerable smaller variations which the drawings cannot depict.

A prominent feature presented in the diagram is that the higher the absolute velocity of the winds, the greater the relative fluctuations which occur in it. In a high wind the air moves in a tumultuous mass the velocity, being at one moment perhaps 40 miles per hour, then diminishing to an almost instantaneous calm and then resuming.

Since the air is an elastic and nearly perfect fluid, subject to condensation and rarefaction, and its motion is practically without friction, the successful velocities of any given particle are in reality the result of incessant changes in all directions, and these continuous

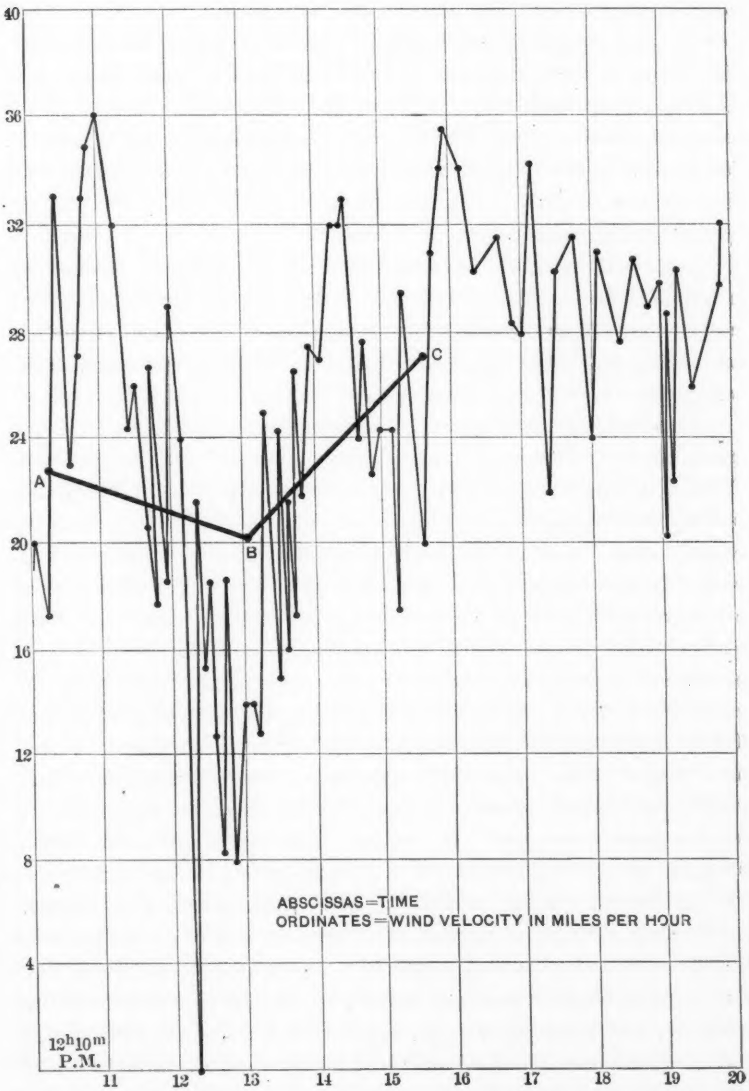
40
36
32
28
24
20
16
12
8
4
A
B
C
ABSCISSAS=TIME
ORDINATES=WIND VELOCITY IN MILES PER HOUR
$12^h 10^m$
P.M.
11
12
13
14
15
16
17
18
19
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FIG. 17.

alterations which make the wind are due to past impulses and changes which are preserved in it and die away very slowly.

Of these irregular movements of the wind which take place up, down and on every side, only a small portion, viz., those which occur in a narrow current, whose direction is horizontal and whose width is only the diameter of the anemometer, can be noted by the instrument. However irregular the movements may appear on the diagram, they are far less so than in reality, and anything like a fairly complete graphical representation is impossible.

As a result of these observations Professor Langley reaches the conclusion that "the wind is not even an approximately uniform moving mass of air, but consists of a succession of very brief pulsations of varying amplitude, and that relatively to the mean movement of the wind, these are of varying directions."

Regarding the direct effect of wind pressure on buildings, some suggestive results were obtained by Professor Kernot* with an apparatus devised to determine the relative pressures of the wind on flat plates, cubes, cylinders and other forms similar to those employed in ordinary construction. A steady jet of air 10 x 12 ins. in cross-section was directed against small models supported on a very delicately arranged carriage running on an accurately leveled surface plate, the force exerted being measured by a delicate spring balance. From a large number of experiments made with this apparatus he found that the pressure on sloping roofs agreed with the results of theory only when the air could blow freely underneath. With the model of a roof placed on a wall, as in an ordinary building, the air was deflected upward and greatly reduced the pressure on the roof; the effect was more marked when a parapet was used. In the case of a roof of 30° pitch, with a parapet 0.16 the height of the roof, the pressure was actually reversed, the roof having a slight tendency to lift. Experiments were tried as to the effect of the wind blowing in at the open end of a building having the sides and other end completely closed, and it was found that there was an internal pressure, tending to lift the roof and force out the sides, which was equal to the pressure of the wind on the exposed end. When a plain surface, paralleled to the wind, was brought nearly nto contact with the cylinder, the pressure on the latter was increased early 20%, owing to the lateral escape of the air around the cylinder

* *Engineering Record*, February 10th, 1894.

being checked, showing that a tower or chimney will be subjected to a much greater pressure if there is a building nearly touching it on one side. The variations of pressure caused by the proximity of other surfaces were very marked; each surface appeared to affect the pressure on the other surfaces to a distance in front equal to its own breadth, and in the rear equal to several times this distance. Behind flat surfaces eddies were found to exist which caused other surfaces placed behind them to be urged forward with considerable force.

The existence of a suction on the leeward side of surfaces or bodies exposed to the wind has been generally recognized, but the experiments of Mr. Irminger,* a Danish engineer, made to determine the amount of such suctions, shows it to be present to an unexpected extent. The measurements were made by the use of hollow plates and models of thin sheet iron exposed in an air duct of 4½ x 9 ins. cross-section, at various angles and positions, to velocities ranging from 16 to 32 miles per hour.

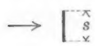
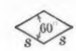
The bodies were supported on a hollow axis closed at one end and connected at the other with a pressure gauge, the axis communicating with the interior through a series of holes. The surfaces to be experimented with had a series of holes which were exposed in succession, one at a time, to the air current and recorded the effect of the wind, whether pressure or suction. In this way both the total effect and the percentage of it that was pressure or suction was obtained.

Although the small size of the models may give rise to some question as to the exact values obtained, the characteristic features of the experiment are so marked and seem to be so generally confirmed by the effect of the wind on buildings in St. Louis, that the results are reproduced here at some length.

It was found that with the wind blowing against the plane at small angles, say from 0° up to 5°, the total effect was due entirely to suction on the leeward side, the pressure on the windward side being zero. With the wind blowing at an angle of 10° on long and narrow planes the total effect was found to be 45% of that due to normal wind suction, and 87% of this was due to suction. With an increasing angle between the wind and the surface acted upon, the effect due to suction was reduced, but never became less than 45%; that is, the maximum percentage of pressure alone was never over 55 per cent.

* *Engineering News*, February 14th, 1895.

In the table are given the results on different-shaped prisms of the cross-section shown. p is the total pressure against the plane surface, the height of which is s; 45% of this total pressure is due to pressure on the windward side, and 55% due to suction on the leeward side. Similarly, the percentage of pressure and suction is given for different bodies, as well as the ratio the total effect bears to the total pressure on a plane surface. In the case of the cylinder, which was examined by boring a single hole in it and revolving it gradually through 360°, it was found that pressure existed only through an arc

PRESSURE IN A HORIZONTAL DIRECTION		PRESSURE ON THE WINDWARD SIDE % TOTAL PRESSURE	SUCTION ON THE LEEWARD SIDE % TOTAL PRESSURE
	p	45	55
	$0.95p$	57	43
	$0.79p$	24	76
	$0.57p$	28	72
	$0.25p$	18	82
	$0.59p$	58	42
	$0.42p$	14	86
	$0.71p$	63	37

of 70° at the front of the cylinder, the remaining four-fifths of the surface of the cylinder showing a suction action.

The most interesting result was that found for a roof sloping at an angle of 45°, as shown in Fig. 18. The pressure on the windward side was a maximum at the eaves, and became zero near the top, changing to a suction at the ridge. The effect on the leeward side was a uniform suction. Taking the normal pressure on a plane of the same dimensions as equal to p, the proportional effect on the windward side was found to be a pressure of $0.11\,p$, and on the leeward side a suction of $0.36\,p$. The resultant effect on the total roof was a force 3½

times as large as the pressure on the windward side alone, and was inclined upward, exerting a strong lifting action. In another experiment made with the model of a building covered by a dome, the resultant of the pressure and suction upon the dome was found to act vertically upward.

The results of these experiments show that the wind acts in a direction quite different from that generally assumed and usually provided for in the designing of bridges, roofs and buildings. The evidences at St. Louis confirm this conclusion.

The meteorological conditions which prevailed during the tornado in St. Louis are fully given in an official report of Mr. H. C. Frankenfield.* The local station is situated in the heart of the city, about 1 mile from the center of the path of the storm.

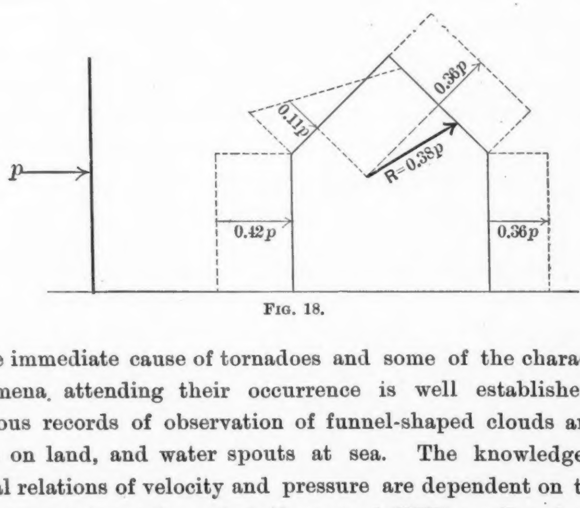


FIG. 18.

The immediate cause of tornadoes and some of the characteristic phenomena attending their occurrence is well established from numerous records of observation of funnel-shaped clouds and sand storms on land, and water spouts at sea. The knowledge of the internal relations of velocity and pressure are dependent on the generally accepted mathematical theory† of William Ferrel, supplemented occasionally in recent years by the records of self-recording meteorological instruments that may be near the vicinity of such storms.

The conditions favorable to a tornado are an unstable equilibrium of the atmosphere caused by an excess of warm and saturated air accumulated under the colder and heavier strata above. The lower strata

* This appeared in the *Bulletin* of the United States Weather Bureau.

† "A Popular Treatise on the Winds."

finally bursting through the upper one at some point and starting an upward flow, the region of ascending currents is kept warmer and consequently rarer, as long as it is supplied with air nearly or quite saturated. The latent heat which is given out by the condensation of the vapor in the rising and expanding air necessarily keeps up the general temperature far above what it would otherwise be.

The great effect which the presence of aqueous vapor in the rising air has on its temperature is more clearly seen by the illustration of assuming a mass of air at sea level at temperature 27° Cent. and pressure 750 mm., to be transported upward without the addition or subtraction of any heat and noting the change it undergoes in temperature, due to the expansion under diminished pressure and consequent cooling. Assuming the three conditions, dry, half saturated, and fully saturated air, the temperature at various elevations and corresponding pressures is given in the table.*

	Elev. 0.° m. Pres. 750 mm.	1 280 m. 640 mm.	2 600 m. 544 mm.	3 750 m. 472 mm.	5 550 m. 375 mm.
Dry	Temp. = 27.° C.	13.3°	0.°	—11 2	
Half saturated	" = 27.° C.	13.3°	6.5°	0.°	—9.6°
Fully saturated	" = 27.° C.	21,2°	15.°	9.5°	0 °

The dry air and the half-saturated air expand and cool equally until the dew point of the latter is reached at an altitude of 1 280 meters, the temperature of each being reduced at that level to 13.3° Cent. The fully saturated air, kept warmer by the latent heat of the moisture, which is continually condensing, has the much higher temperature of 21.2° Cent. With further elevations, the dry air is reduced to a temperature of zero at an altitude of 2 600 m., but the half-saturated air, having passed its dew point, has now been kept warmer by latent heat and has a temperature of 6.5° Cent., the fully saturated air being at a temperature of 15°. The temperature of the half-saturated air becomes zero at an altitude of 3 750 m., and the fully saturated air is not cooled to zero until an altitude of 5 550 m. is reached.

From any slight disturbing cause, the rising currents soon run into rapid gyrations about the center, which generally extend from above downward, the process being an inversion of the familiar comparison of

* Values in the table read from "Hertz' Graphical Solution of the Adiabatic Process" in "Modern Meteorology." Frank Waldo.

the case of water in a shallow basin running out through a hole in the center. The centrifugal force of this rapidly revolving pillar of air causes a rarefaction and consequent cooling of the air near the center which condenses the vapor and forms the water-spout, or the familiar funnel hanging from the base of the cloud. Unless the whirling motion has reached the ground and drawn up dust and débris, the outline of the funnel represents a theoretical line of equal pressure and equal temperature, if the inflowing air is of a uniform degree of saturation; or, in general, it may be considered the locus of the dew point conditions of the ascending and revolving air currents. With an increase of velocity, the rarefaction extends further down, and the funnel lowers. The funnel is always an indication of the gyratory motion of the air, but not necessarily a measure of its action. With various degrees of saturation, different funnels would appear for the same velocity of gyration. With partially saturated air and the central part of the column sufficiently rarefied and cooled to be near the point of condensation, a small change in the gyratory velocity will cause the funnel to suddenly appear throughout the whole length, or as quickly disappear, making it apparently drop down from the clouds and draw back again in a capricious manner. With the air at or near the point of saturation, the cloud will appear very low, and a slight relief of pressure cause a general condensation in which the funnel is not distinguishable. Such were probably the conditions at St. Louis, as the relative humidity of the air was 0.94.

The water spout shown in Plate VIII,* which was observed near Cape Cod, represents an exceptionally perfected example of the phenomenon, and is illustrative of the theory. It occurred about 12.45 P. M. on a warm and sultry day, lasted about 17 minutes and then disappeared, and was followed after several minutes by a second spout, which dropped down from the clouds at nearly the same place, but was not so large and lasted only a short time. There was probably but one column of gyratory air, which became invisible towards the end, when the air at the center became denser, due to reduction of velocity, but with a further increase in the velocity, from some cause, the rarefaction and condensation would again follow and the air at the center again become visible, appearing to the observer, however, as a second and different spout. The photograph was taken at an

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* Reproduced from a photograph copyrighted by Mr. J. N. Chamberlain.

estimated distance of 7 to 10 miles, some six to ten minutes after the spout had been formed. The regular diameter and outlines of the column and its almost stationary position indicate a high degree of uniformity in the conditions of the immediately surrounding atmosphere. There was a great agitation and boiling of the water at the base. The column was estimated about a mile high. The irregular

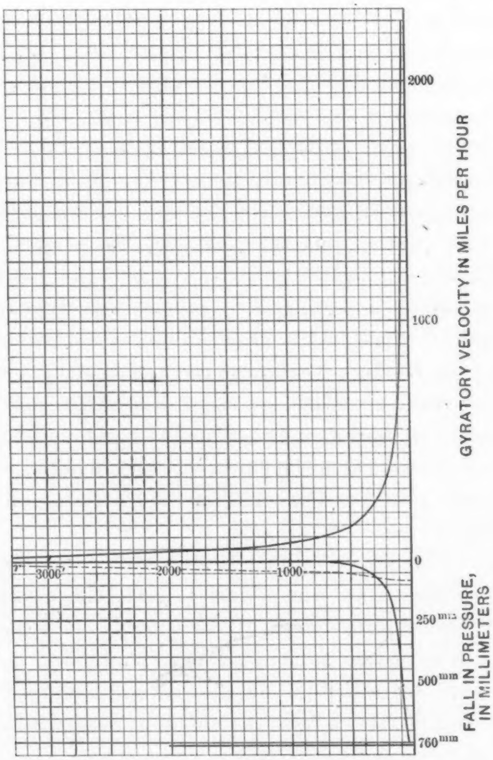

FIG. 19.

form and progressive motion of the second spout show the less uniform conditions which prevailed near the end when the energy had been nearly exhausted.

The equations deduced by Ferrel are based on assumed conditions of no friction, either between the currents of air at different velocities, or between the revolving air and the surface, a gyratory velocity very

PLATE VIII.
PAPERS AM. SOC. C. E.
JANUARY, 1897.
BAIER ON TORNADOES.

great compared to the velocity of the radial or ascending currents, and a continuity of action sufficient to allow the gyratory motions to become uniform. This purely theoretical treatment gives enormous velocities near the center with very low pressure, and a very rapid change for both velocity and pressure for varying distances from the center, which, as Ferrel repeatedly cautions, must be greatly modified for the effects of friction. With the gyrations brought to the surface, the velocities of the inflowing air currents are very small, as the centrifugal force tends to keep them out. To account for the great velocity of ascending currents, Ferrel assumes that the friction at the surface will greatly reduce the gyratory velocity, and consequently the centrifugal force there, and allow the side currents to rush into and rise in the central space of low pressure. The pillar of revolving air, with a hollow center extending nearly, but not quite, down to the surface, acts like a chimney through which the surface currents rush up with extreme velocity.

To illustrate more clearly the conditions existing in a tornado, the tabulated results for one of a number of examples worked out by Ferrel have been plotted, and are shown graphically in Fig. 19. The vertical line represents the axis of the tornado. The vertical ordinates to the upper curve give the theoretical gyratory velocities v in miles per hour, varying inversely as the distance from the center and the vertical ordinates to the lower curve give the theoretical reduction in pressure p in millimeters, each corresponding to the distance r from the center of the tornado, laid off on the horizontal line. The extreme values are near the center and would be very much modified by friction. The pressures at the base would probably be more nearly represented by the dotted line. The high velocities and corresponding intensity of pressure reached by even an approach to these theoretical results convey an idea of possible destruction that may be somewhat misleading as regards its amount, when considered in reference to structural work or buildings. The destructive work done by the winds must depend, not only on the velocity of the air, but also upon the volume in motion. The volume of air having this high velocity is very limited, the same mass revolving around very often. The time of one revolution for various particles of air, computed for the velocities and distances from the center as taken from the curves, appears in the following table and shows this more clearly:

Velocity—miles per hour.	Distance from center.	Time of one revolution.
	Feet.	Seconds.
100	730	34.2
120	610	21.7
150	485	13 8
200	370	7.9
300	245	3.5
400	180	1.9
500	145	1.23

Assuming, for illustration, that an imaginary rigid plane, extending any height above the surface, were suddenly thrust into a tornado, to the center, the pressure on any point on that plane would be such as corresponds to the velocity and density of the particles striking at that point, but it would last only as long as the time of one revolution of such particles. In this case a pressure due to a velocity of 120 miles would last 21.7 seconds, while a pressure due to a velocity of 500 miles would last only 1¼ seconds. This is true in degree whenever a tornado encounters any considerable obstruction in its path. The pressure due to these high velocities may be exerted continuously on small objects, but only for brief periods on large and rigid bodies.

It is needless to say that any theoretical discussion is dependent on perfect or uniform conditions that are the exception in Nature; but the results may be taken to represent a type to which the actual occurrences are more or less similar and in rare cases attain, as in this instance of the water-spout. Even in this case the equations would apply only to the body and have to be largely modified for the base of the spout, where the conditions were not so clearly defined.

The indications in the St. Louis tornado point to a condition similar to the theory given by Ferrel, if very largely modified for surface conditions of friction. The very low barometric readings suggest the interior conditions of the tornado while the destructive action at the surface does not show evidence of that extreme force observed in some other tornadoes and which would necessarily accompany the gyratory velocities required to produce such a fall in pressure. Assuming even an approximate flow of air from all sides into the storm center with the velocity recorded at the Weather Bureau, that is, about 10 miles in 12 minutes, the resulting volume of air to be disposed of is enormous. The existence of a very low pressure at the axis of the tornado, allowing the ready escape of the air upward, would draw it in at the surface and might account for a great inflow from all sides.

In this instance, as is commonly the case in tornadic action, there were probably several tornado whirls, more or less completely developed, but not extending quite to the surface, which passed over the district and created an area of very low pressure, with a resultant influx of lateral air currents at very high velocities from all sides, the latter being probably the immediate cause of most of the destruction. The records of the Louisville tornado, as given in the Weather Bureau reports, show that most of the damage there was due to the lateral currents toward the center. The general indications and a sequence of well-established incidents show very clearly that the damage to the St. Louis Bridge was caused by lateral currents rushing into the vortex which passed on the south side of the bridge as it progressed eastward.

Allowing for the heavy proportion of the damage due to flying débris acting as projectiles, and to the direct action of the wind in blowing in one wall and successively taking out the others, there still remains a large percentage of destruction which was the result of the explosive action due to the difference in pressure of the air on the inside and outside of buildings. There were numerous instances of partial destruction which showed this action very clearly. The immediate cause for this difference in pressure is a matter of some speculative interest.

The great reduction in atmospheric pressure in the center of tornadoes is a possible cause. While, however, the possible destructive action of such variations in pressure is enormous, the extent to which it is realized is dependent entirely upon the rapidity of the change. If the rate of change is gradual enough to allow the confined air to escape and equalize the pressure inside of the house, there will be no damage due to this cause. That this change of pressure is a more or less gradual process is evident from the fact that the variation of 2.4 ins. in the mercury barometer, which is equivalent to 168 lbs. per square foot, would, if instantly applied, completely burst open any ordinary house.

The fact that the low reading on the aneroid in the storm was noted before the advent of the extremely violent wind, and also the marked effect on the barometer at the Weather Bureau, are further indications that this change in pressure was a gradual one in this instance. Assuming that the effect of a possible reduction of 3 ins.

in the atmospheric pressure, as measured by a mercurial barometer, is felt at the distance of a mile, and that the tornado moves at the rate of 40 miles per hour, the entire variation in pressure would be effected at any one point in 1½ minutes. To equalize the pressure for such a change, about one-tenth of the air confined in a building must escape. For an ordinary room, say 20 x 15 x 10 ft., having a capacity of 3 000 cu. ft., this would mean a flow of 300 cu. ft. in 1½ minutes, or an average rate of 200 cu. ft. per minute. If this rate is assumed as not uniform, but as having a possible maximum at some time of twice that amount, the flow must be 400 cu. ft. per minute. Under a difference of pressure of 10 lbs. per square foot, the flow of air through an ordinary 6-in. stove pipe may be about 500 cu. ft. per minute. Through an open fireplace with an ordinary 9 x 9-in. flue, the flow of air may be 1 000 cu. ft., or a single window with an opening of 1 in. will accomplish the same result. A house that is entirely closed, in the ordinary sense of the word, would have an amount of leakage through the doors, windows, chimneys or ventilating flues that would go far to equalize any but the most sudden change in pressure.

The observations of Prof. Langley show that the wind under ordinary conditions is subject to continual fluctuations in velocity varying from 20% to 50% from the average, and that these variations become greater at higher velocities. The conditions prevailing in a tornado must give rise to the most violent local action of the wind. The internal irregularities which are caused by the motion of great volumes of air rushing with accelerated velocity towards a common center are rendered still more complex by the usual presence of aqueous vapor at its critical point with the attendant dynamic changes due to the expansion, cooling, condensation and latent heat. The presence in the air of the aqueous vapor, with these transformations gradually but continually going on, is recognized by meteorologists as the chief cause of local disturbances of the atmosphere. That a storm with the air at the point of saturation will cause much greater damage than one under similar conditions as to intensity of wind, but with the air dry, as noted in a previous discussion* before this Society, is further evidence of the greater irregularity of the wind due to this cause. If the velocity of the ordinary wind will vary 50% from the average, it is quite probable that the velocity of the inflowing currents of air at

* *Transactions*, Vol. xxxiii, p. 214.

the base of a tornado may vary locally from nothing to double the average or more, and that there may be, at any point, a momentary calm followed immediately by a surging mass of air with a velocity approaching or equal to that due to the gyratory motion of the tornado itself. When these irregularities in the wind are further complicated by the effects of the broken surface conditions due to the houses and streets of a closely built city, with the attendant obstructions, eddies and deflections of the currents, the motion of the air must become infinitely complex and capable of almost any vagaries.

The apparent inconsistency so frequently seen of a weak and frail structure with equal exposure escaping close to the general destruction of a stronger building is the most conclusive evidence of the unequal action of the wind.

If the characteristic effects of the wind, as known by observation and experiment at ordinary velocities, are maintained and correspondingly intensified for the high velocities attained for brief periods over limited areas by this gusty and irregular action, the destruction is readily explained.

The familiar sight of the little whirlwinds that suddenly appear and move along the road or street for a few minutes, on a windy day, picking up leaves, dust, or paper, give but a faint idea of the possible effects of the many local whirls, of varying magnitude, that must be continually formed when the atmosphere is in such an extremely agitated and unstable condition. The meeting of sharp extreme gusts of wind will create a whirl with an instantaneous fall of pressure over a small area at the axis, the latter being not necessarily vertical, but may be horizontal or at any inclination. If such a whirl be formed with the axis against a building, the sudden relief of pressure over a very small area will cause an immediate explosion of part of the building.

The wind blowing into a building will quickly pack the air and create a pressure and blow out the weakest accessible part, either wall or roof. This is particularly effective with large or high spaces unbraced by cross-walls or partitions.

The suction found to be present on the leeward side of obstructions to the wind may account for a great amount of damage. A wind with an average velocity of only 80 miles per hour might under extreme conditions have fluctuations of 120 to 160 miles per hour. Assuming the values found by Irminger to be approximately correct, such a wind

blowing over the top or past the side or at an angle against a building would give a suction of 20 lbs. to 40 lbs. per square foot, acting instantaneously and giving no time for the pressure to equalize. The same experiments show that the wind blowing over the sloping roofs so generally found on churches will create a suction that tends to raise the covering off of the trusses, an occurrence that was observed in numerous instances. The frequently observed stripping of patches of slate out of sloping or mansard roofs is also readily accounted for by this action.

The very general and repeated evidences as to the variable action of the wind suggests the desirability of further observations of velocities recorded at shorter intervals than the nominal passage of every mile of wind as is customary in meteorological practice. A wind registering every 45 seconds is necessarily interpreted as representing a uniform velocity of about 60 miles per hour, while in reality there may be velocities of 90 or 100 miles or more in several successive gusts of five to twenty seconds' duration, long enough to overcome the inertia of the heaviest structure. It is these destructive velocities that chiefly concern the engineer, and any deductions as to pressure made from ordinary velocity records may be very misleading.

The records of the Weather Bureau, valuable as they are, could be made of still more service to the engineer if supplemented by a knowledge of such fluctuations from the average velocity as may exist in severe storms and under varying conditions as to temperature, humidity or barometric pressure. The experiments of Professor Marvin on Mt. Washington were made with very low barometer, 23.9 ins., and in the prevailing foggy weather; that is, in saturated air. Such information could be readily obtained at any of the regular stations by occasional observations taken with an additional anemometer and a chronograph adapted to such service.

The salient features of the St. Louis tornado may be summarized as follows:

An extremely low atmospheric pressure accompanied by a great inflow of violent and gusty lateral air currents, with an intensity of pressure estimated at 58 lbs. per square foot. A second instance of severe wind pressure, estimated at 85 to 90 lbs. per square foot, may have been due to the gyratory velocity of the tornado.

IV.—High Buildings.

Much of the destruction in St. Louis was undoubtedly caused by an intensity of wind pressure that it would be neither possible nor expedient to provide against in ordinary structures, but much of it was also due to weak construction. A general observance of the ordinary requirements for good building work would largely decrease the damage due to such storms. The great amount of explosive action was largely due to the comparative weakness of ordinary walls against pressure exerted from the inside of buildings. A more efficient anchorage of the walls might limit this explosive action to the windows. In numerous instances the windows were blown in on the windward side, while the entire wall was blown out on the leeward side. Brick walls are materially stronger if well bonded with the vertical joints filled with mortar, and a wall laid in cement will undoubtedly withstand a greater lateral force than one laid in lime mortar. It is worth nothing that the walls of the buildings of the Union Depot Railway plant left standing (Fig. 1, Plate III) were laid in cement, while the older buildings, which were entirely wrecked, had walls laid with lime mortar. The great damage done to the churches calls attention to the great exposure of the steep and lofty roofs supported on high and comparatively thin and unbraced walls. Heavier buttresses or independent steel column supports, with bracing for the roof trusses, would materially increase the safety of such structures. In general, the buildings with large areas of unbraced walls have suffered most.

The lofty office buildings common to the large cities represent an expenditure of money that justifies careful provision against any destruction that may arise from even exceptional wind pressures. The question as to what would be the effect of a tornado on these high buildings is one that has probably occurred to every engineer and architect.

The periodic prevalence of these storms emphasized by the recent calamity in St. Louis, by the destruction in Louisville in 1890, and by a similar storm in Little Rock in 1894, and in Kansas City in 1886, gives a somewhat broader public interest to this question, and appears to call for its serious consideration. The evidence of the work of the wind in St. Louis suggests as an immediate answer to the question

that it will depend largely upon the nature of the metal framework in the building.

The high office building represents the outcome of an evolution in architectural and constructive design dictated by the commercial necessities of the age. The tendency to the concentration of business interests within small areas, the excessive high values of land, and the necessity of realizing an adequate return on the investment, demand a building with many floors and the maximum rentable space on each floor—a high building with thin walls. The replacement of the heavy exterior masonry by the lighter veneer or curtain walls and the consequent gain in available floor space has been made possible by the use of an iron or steel framework, primarily introduced to carry the vertical loads only, but gradually modified and strengthened in accordance with an increasing recognition of the need of providing lateral strength and stiffness against wind and other destructive forces. There still exists, however, a great diversity in the treatment of this feature of the design.

The metal framework of a building is somewhat generally called the "skeleton" and sometimes a "cage." If both of these terms are to be retained in this special sense, a convenient distinction can be made by some restriction in their use suggested by the words themselves.

Skeleton is a term clearly descriptive of that type of construction to which it was first applied, a simple framework of columns and beams whose efficiency is dependent largely on the existence of exterior walls and partitions which brace the building, and hold the framework in position, just as the utility of the human skeleton is dependent on the covering of sinews and muscles that hold the component parts together. On the other hand, the light framework of an ordinary wire cage bound into one compact unit is suggestive of an inherent strength and elastic resistance that renders any covering an incident rather than a necessity. Cage is a term peculiarly descriptive of that type of construction represented by the most advanced and approved practice, a framework of columns and beams, spliced at the joints, riveted at the connections, stiffened by an efficient bracing of rods, portals and gussets that makes it independently safe against any external force, leaving the thin and light exterior walls with no duty except that of providing protection and ornamentation for the building.

The effect of an extreme wind pressure on a high office building with curtain walls must depend largely on the extent to which the frame of that building partakes of the nature of the skeleton type or the cage type of construction.

The possible work of destruction of a tornado may appear more clearly if, as Ferrel suggests, the column of rapidly revolving air is likened to a tall flue, with heated and rarefied air in its interior. If the access of air is cut off from the lower central part by the shell of gyrating air extending down to the surface, the lateral currents and ascending currents in the interior will be of no violence, but with a somewhat free access of air below into the rarefied interior, on account of a decrease by friction of the gyratory velocity near the surface, the inrush of lateral air currents becomes extremely violent and the velocity of the uprush of air in the interior becomes enormous. In the former case the destruction is mainly due to the excessively high gyratory velocities; the destruction is complete, but the path narrow. It is the condition that may prevail in open country with but few objects to destroy the energy of the tornado. In the latter case the destruction is largely due to the violent lateral inrushing currents. The path is wider, and the force not so extreme. It is the condition which must prevail in any compactly built city, owing to the great friction of the air arising from the irregularities due to the many buildings.

The first high isolated building encountered will feel the full force of the gyratory velocity, but the resistance of the building destroys this velocity and the work of destruction wrought on that building must represent an equivalent diminution of energy in the lower section of the tornado, which can only be renewed by its further unobstructed progress during such appreciable time as is necessary to restore the gyratory velocity. A succession of high buildings will prevent such recovery of velocity.

The destructive power of a tornado on massive building work due to these excessively high velocities is therefore soon exhausted, but the wind pressures due to the violent currents rushing in from all sides are only intensified thereby.

If a tornadic storm with a well-developed whirl should pass through the section of any city containing very high buildings, the general level of the top of the lower buildings becomes equivalent to the ground surface, and it seems fair to assume as the result the

same general action that has been found near the surface, modified or intensified in its irregularity according to the degree of uniformity in the general height of the majority of the buildings. There may be the extreme pressures due to the gyratory velocity of the tornado proper exerted over a limited area and for a very limited time. There will be a far wider zone of lateral inrushing winds at high velocities lasting throughout the progress of the tornado and attended by the additional complications that may arise due to the concentration of air currents in the deep valleys formed by the streets between the buildings. The probable result would be an extremely variable and intense action of the wind about the tops of the lower buildings, the same action concentrated locally at about that level on the higher buildings, accompanied with a general severe pressure over the entire exposed area of the latter, this latter pressure probably being a maximum near the top or at least some distance above the general level where the friction is not so great.

A characteristic feature of the St. Louis tornado, and one which, judging from records and published views, is also common to other tornadoes and violent hurricanes, is the general destruction of the ordinary brick and stone walls. Regardless of the sequence in which they may explode outward or are blown inward, and of a possible difference of opinion as to whether the explosion is due to a plenum, a vacuum or to a suction, the essential fact remains that the walls do very generally fall.

Assuming a similar action of the wind, the buildings of an average height will probably have the walls at the top or exposed corners destroyed, or, if particularly weak, may be shaken down. The buildings above the average height would be very liable to have part of the walls at any level blown in or taken out. An office building with the curtain walls of one or more stories removed would support the remaining enveloped superstructure precisely in the manner of the grain elevator before it was struck by the storm.

If, now, the building is of the pure skeleton type, it will have only the elements of stability that existed in the case of the elevator—its weight—above the floor in question, and possibly some additional bracing of a more or less uncertain value, and under the action of even such pressure as may exist at some distance from the vortex of the tornado, it will fail, just as the elevator failed; it will topple over

and fall to one side or towards one corner on the floor below. Instead, however, of landing on a massive stone foundation, the thousands of tons of weight of the three, four or six stories, as the case may be, of the upper section of the building will fall with a crushing force, concentrated on the leeward side, on the section below. The heavy oak girders under the leeward edge of the elevator were mashed into a bundle of splinters, while the windward edge was held some distance above the foundation. As the striking force of a freely falling body is equal to the product of its weight multiplied by the distance through which it falls, about 12 ft. in the case of an office building falling one story, the resulting pressure on some of the columns may easily be ten to twenty times the load they were designed to carry and several times their ultimate strength; the result must be a collapse of part or all of the lower section, with a possible toppling over of the upper section to one side into the street or on a lower adjacent building.

If the building is of the cage type, it will stand safely under a wind pressure that will destroy the skeleton building. While the failure of the walls at any story may reduce the rigidity somewhat, it cannot affect the strength of a framework designed without placing any dependence on the covering. Such a framework will readily carry the lateral stresses from the upper section to the section below.

If the pressure should reach a destructive intensity, the exact line of yielding of a cage frame is not so clearly defined. The tendency to lateral displacement will be a maximum at some one story, depending on the distribution and cumulative effect of the wind pressure aided possibly by the weakening due to localized failure of walls or partitions. As the frame is of a gradually varying strength from the top down, the distortion can hardly be confined to one level, but would probably involve the members of the adjacent stories, the effect being a general racking or leaning of the building. With strains near the ultimate strength, the failure at some point may concentrate a distortion at that level, and the upper section of the building may be pushed to one side and ultimately settle down on the floor below.

The essential difference lies in the fact that a wind of sufficient force and duration to push the upper section of a building to one side a distance about equal to the width of a column may cause total destruction in a skeleton building, while a cage under the same circumstances

may suffer only a local damage that can possibly be repaired at a comparatively small cost. In a skeleton building, the instant the columns are pushed beyond the critical or balancing point, the weight is reversed in its action from an element of safety to an almost unresisted element of destruction. With a cage type of construction the weight of the building after some displacement has taken place also acts with the wind as a destructive agent, but not unresisted. The work that must be done in the necessary bending, twisting and general distortion and breaking of the metal in the columns and beams must largely absorb the energy of the falling mass and have the effect of letting it settle down on springs. The local peculiarities of the building, the unequal distribution of the wind pressure, and the changing direction of the wind, make it more than probable that such failure will not be symmetrical, but will have a torsional effect on the upper section of the building.

However difficult it is to foresee the many possibilities, it is safe to assume that in one way or another the framework will hang together sufficiently to prevent any considerable part of the building from falling down bodily on to streets or buildings below. Even under the most extreme conditions it is difficult to conceive how such a building, or a large part of it, can entirely collapse. The general destruction of windows and walls will greatly relieve the wind pressure, the frame, partly bent, twisted and distorted, must still hold together. The chances are that most of the occupants will escape alive and many uninjured. The most striking feature of the St. Louis tornado is the countless number of hairbreadth escapes and the very small number of people killed inside of houses unless by the entire collapse of the structures; incredible as it may seem, under such extreme conditions, the fatalities attending only local failure of a building are comparatively few.

The effect of a destructive wind pressure on any high building with curtain walls may be assumed to approach that outlined above in proportion as its framework partakes of the nature of a skeleton or cage type of construction, using these terms in the restricted sense indicated in this paper.

The destructive effect of the total collapse of buildings has been too frequently noted to require further mention. The method of failure of the grain elevator, taken in connection with the view of the wreck

of the skeleton framework in Fig. 1, Plate VI, indicates what might happen to a high building of the pure skeleton type if brought to the point of failure. The assumed action of the cage type of building is dependent on an efficiency in general design, and particularly in the detailing of connections which can be readily attained if the necessity for it is recognized. In the absence of any definite tests of full-sized typical details used in the structural work of buildings, the action of the metal under extreme distortion must be estimated from the results shown by sample specimens, verified by occasional opportunities to notice its behavior under accidental tests of great severity that may be caused by collisions or derailments on or near bridges and viaducts. The riveted joints mentioned earlier in the paper show what may be expected in details involving similar principles of design.

The possibility of a high office building being actually subjected to a destructive wind pressure has often been considered largely in the light of a theory. The St. Louis tornado passed within less than a mile of the office buildings in that city. Fortunately it made no test of the buildings, but it has left some definite evidence of the possible force of the wind and of the action of this force on the materials of construction. While it raises anew the question as to the amount of wind force which should be provided for in designing high buildings, it raises with more emphasis the question as to the method of providing for this force after its amount has been assumed. Any dependence placed on curtain walls and partitions for lateral strength is open to very grave question. The rigidity imparted to a building by the simultaneous action of the total mass of material under ordinary conditions is no indication of the ultimate strength that may be developed at a critical moment, and the very general failure of the walls under extreme wind pressure further destroys any certainty of such assistance as might be otherwise relied upon. The elements of safety against wind force, exclusive of the strength that may come from the walls and partitions where they exist, are the stability due to weight alone, stability due to the strength and stiffness of the frame, and, when the force is a sudden one, the inertia of the mass resisting motion.

It may be of interest to estimate just how sudden and how shortlived the force must be to justify placing any dependence on the inertia of the structure for safety. The force required to set in motion and move over a given distance any mass, otherwise balanced, is capable of exact compu-

tation if the time allowed for such motion is known. The equation is derived from the law for falling bodies and is $F = \frac{2\,w\,d}{g\,t^2}$, where F is the total force, w the weight moved in pounds, d the distance moved over in feet, t the time in seconds, and g is 32.2.

The following table, computed from this formula, gives the force required to overcome the inertia of a ton of 2 000 lbs. and move it varying distances in times varying from one second to thirty seconds.

FORCE PER TON REQUIRED TO OVERCOME THE INERTIA OF AND MOVE ANY GIVEN MASS.

TIME IN SEC.	DISTANCE MOVED.									
	1 in.	3 ins.	6 ins.	1 ft.	2 ft.	4 ft.	6 ft.	8 ft.	10 ft.	16.1 ft.
1	10.3	31	62	124.22	248	497	745	994	1 242	2 000
2	2.6	7.7	15.5	31	62	124	186	248	310	500
3	1.15	3.4	6.9	13.8	27	55	83	110	138	222
4	0.64	1.94	3.9	7.7	15.5	31	46	62	77	125
5	0.41	1.24	2.4	4.9	9.9	19.8	30	40	49	80
6	0.28	0.86	1.72	3.4	6.9	13.8	20.7	28	34.5	55
8	0.16	0.48	0.97	1.94	3.8	7.7	11.6	15.5	19.4	31
10	0.10	0.31	0.62	1.24	2.4	4.9	7.4	9.9	12.4	20
15	0.046	0.14	0.27	0.55	1.10	2.21	3.3	4.4	5.5	8.9
20	0.026	0.078	0.155	0.31	0.62	1 24	1.86	2.5	3.11	5.0
30	0.012	0.035	0.069	0.138	0.28	0 55	0.83	1.10	1.38	2.22

Assuming as an illustration the weight of a ton suspended as a pendulum by a very long cord, then to swing it 1 ft. in one second will require a force of 124.2 lbs., while the mere pressure of 1¼ lbs. will accomplish the same result if the time allowed is 10 seconds, or about the average duration of a gust of wind in Professor Langley's experiments. Applying the figures in the table to the case of a narrow building, say 32 ft. wide, and assuming the upper section 100 ft. high by 100 ft. long, having thus an exposed area of 10 000 sq. ft., to weigh 5 000 tons, then the force necessary simply to overcome the inertia and move this part of the building the respective distances of 1 in. or 1 ft. or 16 ft., in various intervals of time, is equivalent to a pressure per square foot of the exposed areas as follows:

t.	$d = 1$ in.	$d = 1$ ft.	$d = 16$ ft
1 second	5.2 lbs.	62.1 lbs. per square foot.	1 000 lbs. per square foot.
2 "	1.3 "	15.4 " " "	250 " " "
3 "	0.5 "	6.9 " " "	111 " " "
5 "	0.2 "	2.5 " " "	40 " " "
10 "	0.05 "	0.6 " " "	10 " " "
15 "	0.02 "	0.3 " " "	4.4 " " "

These figures will readily indicate how great a resistance the inertia of a building may be against the motion necessary to overturn it under the action of a brief gust of wind, and how comparatively little this resistance becomes as against only such motion as is necessary to push it over on its supports. To overturn the building in 10 seconds a pressure of 10 lbs. per square foot is necessary to give it the necessary motion in addition to the force required to overcome its stability. The resistance of inertia for a movement of 1 ft. against a gust five seconds in duration will be 2.5 lbs. per square foot, and for 10 seconds it will be only 0.6 lb. per square foot. For shorter periods the value of inertia becomes very high, but may on the other hand be entirely overbalanced by the cumulative effect of the vibrations of the building acting in rhythm with the pulsations of the wind. Experiments on Chicago buildings under heavy winds show the time of a complete vibration to be about two seconds. The resistance of inertia against the destructive effect of brief but intense pressure, such as the gyratory velocities in the vortex of a tornado, is fortunately very great.

Stability due to weight alone is proportional to that weight and to the breadth of base of the support. Its value as an element of safety is a most definite one, and may be sufficient. Considered with reference to overturning, a large elevator or building may be safe beyond all question, yet with reference to its column supports the same structure may be in comparatively unstable equilibrium, as a relatively small movement of the center of gravity will throw it out of balance. The total force required to overturn a building of a given weight increases directly with the breadth of that building, but the total force required to push it over on its supporting columns is a constant depending solely upon the height and breadth of base of those columns, and is independent of the dimensions of the building, of the number of supporting columns, or the material they are made of. Any structural member that is used simply as a prop or support can have only such value as is incident to that use, whether it is made of wood, of stone, of cast iron, or of steel.

The elements of strength and safety inherent in a well-designed cage built of the proper material, with all its members thoroughly riveted together, are present in that frame in greater or less degree, until it is torn or cut apart piece by piece. A steel frame built to be

safe for a wind pressure of 30 lbs. per square foot proportioned by unit strains of one-half the elastic limit would probably withstand a pressure from 40 to 80 lbs. per square foot before the frame yields. This range depends largely on the care with which the connections have been detailed, the extent to which possible unequal settlement of the foundations has already overstrained the frame, and on the reduction of the effective surface exposed to the wind by the destruction of the walls in the panels between the framework, leaving part of the wind to blow through unresisted.

The details of construction that provide lateral strength and safety against an assumed wind pressure are of the first importance. The subject of this paper, however, suggests a further consideration of these same details of construction assuming that they may be strained by wind pressures beyond their safe limits. If a building is never under any circumstances to fail, the problem is completely solved as soon as it is designed to stand under the assumed pressure. Assume that it may some day be brought to the point of yielding, and immediately some pertinent questions arise as to the possible results.

While the destruction and loss of the upper section of a building may be a matter of serious consideration to the owner, the disposition which a tornado would make of that section of the building may be an equally or more serious matter to the adjoining property-owners. If it is impossible to foresee the extreme force of the elements or impracticable from economic reasons to provide against them entirely, it certainly is rational to make such modifications in a design as will reduce the possible disaster and damage to a minimum. A very material increase of safety in this direction can generally be secured at a comparatively small additional expense, depending largely on the attitude of the designer to the problem. The design of a building to be subjected safely to a given wind pressure and never to any more is a definite problem involving only arbitrarily fixed working stresses. A design of that same building for the same condition of safety but with the further recognition of the fact that it may be exposed to destructive pressures and with an effort to develop the ultimate strength and resistance of the material in the cage to resist those pressures, is a problem that will develop some additional considerations.

A destructive lateral force exerted against the upper section of the building will not be lost or dissipated but must follow some well-de-

fined path till it reaches the foundation. If a building is to fail laterally, then the ultimate strength of members under the action of lateral forces becomes of the first importance. Upright members are no longer simply columns, but are more properly considered as vertical beams carrying some initial load, and, viewed in that light, must have all the essential elements of a good beam. The unequal straining and successive failure of the rivets, due to their unsymmetrical distribution in the connections, may become an important element of the design when the stresses are sufficient to overcome the averaging effect of the frictional resistance. The relative values of the ultimate or elastic limit stresses may suggest details at the connections somewhat different from those indicated by the fixed ratios of assumed working stresses.

A brief analysis of possible results applied to the definite circumstances and conditions of any particular building may suggest probable failure along one or several well-defined lines, and as readily suggest modifications that will materially increase the strength of the structure, or at least define and limit the amount of destruction.

The amount of metal required for an efficient system of wind bracing is but a small part of the weight of the metal in the entire frame, and the cost of the latter is only about 10% to 20% of the expenditure for the entire building, exclusive of the site. The cost of the wind bracing can represent, therefore, only a very small proportion of the total capital invested. When it is considered that any additional metal used to strengthen the cage as a precaution against wind force is equally effective against possible damage due to earthquake shocks or to the unequal settlement of the foundations, and is also an additional margin provided against the weakening effect of corrosion, the slight increase in cost must appear trifling as compared to the amount of the entire investment and the additional protection secured for the property.

It is somewhat unfortunate that the merits of the design of the framework are not so readily apparent to the investor, and that this part of the structure is of necessity immediately covered and permanently concealed from view. If the difference in strength and security due to the construction of the frames of some of these great buildings were as generally evident, as, for instance, the difference in strength due to the varying thickness of solid masonry walls was in

older forms of construction, there would probably be a more general recognition on the part of the owners of the need of securing the best type of framework.

A discussion of the safety of high buildings is applicable to other high structures, such as chimneys, shot towers, water towers, etc., and suggests that the development of the cage construction in buildings to its present advanced type makes it equally available for other structures of the kind named above. Monuments built with no consideration of expense will find ample security in their weight, but for any high structure in which cost and security are both of importance, the cage type of construction is thoroughly applicable and may have special advantages. The saving of material in the walls, and particularly in the foundations, may more than equal the additional cost of the steel work when designed for the same strength and security. The objection to any open tower built of structural metalwork in a city on the score of its inherent ugliness is removed by adopting such treatment as the architects have developed in the design of high office buildings. Any shaft or high structure that has lines of stability can be readily supported on a steel cage that will not interfere with its outlines, with probably a great gain in safety.

The amount of wind pressure to be provided for in the design of high buildings will no doubt be variously estimated, depending on the weight given in the judgment of the designer and of the owner of the building to the probability of exposure to such pressures. The statistics as to the frequency of tornados given in the appendix show that the possibility of their occurrence cannot be entirely disregarded without assuming some appreciable risk. While the atmospheric conditions which are favorable to their formation are more common in some regions than others, it is impossible to feel assured of entire immunity from their occurrence in any city. Tornadoes usually occur as local manifestations accompanying severe storms of great extent. On the date of the Louisville tornado there were ten others in the four adjacent States. On April 11th and 12th, 1893, there were nineteen tornadoes in ten States attending severe storms, reaching from Mississippi to Michigan. The St. Louis tornado was but one of a number accompanying a general storm that moved through Missouri and Illinois. As far as known it was not more violent than many others that have been observed. Its great destructiveness was merely incidental

to the fact that its path crossed a territory embracing a large and closely built city. It gave evidence that wind pressures existed at least equivalent to or greater than 20 lbs., 58 lbs., and 85 to 90 lbs. per square foot over considerable areas. Whatever the actual distribution may have been, the effects were those of such pressures uniformly distributed over the areas of the respective structures. These pressures were measured by their results in exactly the same manner in which they are ordinarily assumed to act, with the consequent elimination of all uncertainties usually involved in readings of pressure gauges or deductions from anemometer records, and they are to that extent positive and definite. In addition, there were indications that a pressure of somewhere from 20 to 40 lbs. was quite general over a comparatively wide area in, or adjacent to, the path of the storm, and that the pressures at higher altitudes were more severe than those measured.

In view of these facts it appears to the author rational to assume:

First.—That the safety and interests of the community and of the owner of the building require a recognition of a wind pressure of at least 30 lbs. per square foot against the exposed surface of the building, with an additional local provision of 50 lbs. for several stories near the top; and that this amount should be safely taken care of by some positive and definite provision in the construction of the frame.

Second.—That the vast interests at stake, the amount of capital invested and the comparatively small additional expense necessary would suggest to the owner the desirability of increasing the provision to 40 lbs. per square foot.

Third.—That the other uncertain elements of safety due to the ultimate strength of the material, the inertia of the mass, and the bracing effect of walls and partitions, should be recognized only as providing against the uncertain and possible higher pressure of the wind which may occur.

The chief justification of much that seems bold or questionable in the construction of some high buildings lies in the fact that, as yet, none have failed. If the safety of such great structures is to be determined entirely by the logic of the fitness of the survivor, based on a brief and favorable experience, rather than by a rigid analysis, by tried and accepted principles of engineering design, it may ultimately lead to some very deplorable results.

By such a test the little summer pavilion in Lafayette Park must take precedence over the approach to the Eads Bridge, for it survived the tornado and is standing yet.

The author is indebted to Willis L. Moore, Chief of Weather Bureau, and to H. C. Frankenfield, Local Forecast Official, for their continued courtesy in furnishing the use of records and information of that department; to A. H. Fredericks, President of Board of Assessors of St. Louis, for the data relative to general storm damages, and to many others, too numerous to mention, for their kind assistance in securing much of the detail information that appears in the paper.

APPENDIX A.

THE TORNADO OF MAY 27TH, 1896, AT ST. LOUIS, MO.

ABSTRACTED FROM REPORT OF H. C. FRANKENFIELD, LOCAL FORECAST OFFICIAL, IN *Monthly Weather Review.**

The tornado which passed through St. Louis late in the afternoon of May 27th was the culmination of a protracted period of abnormally high temperatures, intensified during the latter portion of the time by unusually high humidity. From April 9th to May 27th, both inclusive, a period of forty-nine consecutive days, the mean temperature at St. Louis varied from 2° to 21° above the normal.

At 8 A. M., May 27th, the weather map showed the pressure to be low throughout the West. The position of the State of Missouri in the southeast quadrant of the storm area, combined with the isothermal conditions, the high humidity, and the high temperatures, indicated the occurrence of severe local storms within a short time. At St. Louis at 8 A. M., the pressure was 29.92 ins., the temperature 70°, and the relative humidity 94 per cent. By 2 P. M. the barometer had commenced to fall rapidly, and the winds had changed to southeast, with slowly increasing velocity. The fall in pressure was intermittent, but at the same time persistent, and by 6 P. M. the reading was 29.59 ins., a fall of 0.28 in. since noon, and a fall of 0.09 in. during the twenty minutes immediately preceding. The winds continued from the southeast with gradually increasing velocity until 5.45 P. M., when they changed to east-northeast, with a sudden increase in velocity, reaching 45 miles per hour from 5.55 to 6 P. M.

* Records are given in standard time, which is 1 hour 1 minute faster than local time.

At 3.45 P. M. the temperature commenced to fall, and by 6 P. M. had fallen 9 to 77°. The clouds slowly increased in density, and at 3.35 P. M. the sun was obscured. The character of the clouds changed about this time to cumulus, but of a very peculiar formation. The whole sky was compactly covered with small cumuli of almost perfect hemispherical shape, but with the rounded portions underneath.* Their color was a dark gray, with deep shadows on the sides farthest from the sun. By 4.30 P. M. these clouds had settled into a uniform covering of stratus, which commenced to assume a light green color in the extreme northwest, spreading more toward the west and north. Thunder and lightning commenced at 5.06 P. M., and rain in the form of large, scattered drops, at 5.43 P. M. At 6.04 P. M. there was a marked increase in the violence of the storm, although from 6 to 6.10 P. M. the winds changed again to southeast, with decreased velocity of from 33 to 36 miles per hour. During this period the barometer rose 0.08 in., to 29.67, and fell almost instantly 0.10 in., to 29.57. It again rose 0.10 in. in less than five minutes to 29.67. During the next fifteen minutes (to 6.30 P. M.), it fell 0.31 in., to 29.36, and then instantly rose 0.40 in., to 29.76. It then continued in a series of sharp oscillations of from 0.05 to 0.10 in., until 10 P. M., when the oscillations became smaller, ceasing finally at midnight, when a steady rise commenced.

The winds at 6.10 P. M. once more changed suddenly, this time 180° to the northwest, and with greatly increased velocity, reaching 80 miles per hour from 6.15 to 6.20 P. M., with an extreme velocity of 120 miles per hour at 6.18 P. M. At 6.20 P. M. the direction once more changed, this time to the northeast, with a decided decrease in velocity, falling to 7 miles per hour at 6.55 P. M.

The storm entered St. Louis from the west. The time, as nearly as can be estimated, was 6.10 P. M.

The path through the city was almost exactly in a due easterly direction, reaching the Mississippi River, about 6 miles distant, at 6.20 P. M., showing a progressive velocity of about 36 miles per hour.

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* Note added by Mr. Frankenfield, June 23d, 1896: "I have just learned of the height of the barometer, within a reasonable degree of accuracy, in or very near the center of the track of the tornado at the time it moved through Lafayette Park. It was in this park that the storm was at its height. An aneroid barometer, with a metrical scale, was brought to me to be reset, and I was informed that it was the property of the widow of the late Richard Klemm, ex-Park Commissioner of this city. The family live on Missouri Avenue, immediately fronting the park, and a son of Mr. Klemm read the barometer as the storm struck their place. He called the attention of his mother to the remarkably low reading, 680 mm., or 26.78 ins. Allowing for difference in elevation and reduction to sea level, this would indicate a reduced reading of 27.30 ins., or 2.05 ins. lower than observed at this office."

APPENDIX B.

CORRECTION FOR OBSERVED WIND VELOCITIES.

The velocity of the wind is very generally measured by some form of the Robinson cup anemometer. From early experiments it was found that the distance passed over by the center of one of the revolving cups would, if multiplied by three, give about the velocity of the wind, and the wheels and recording dials of the instrument were geared to read wind velocities directly by taking into account this factor of reduction. Later experiments have shown that with anemometers of the size commonly used this ratio is erroneous, and the indicated velocities are about 20% too great, but no change has been made in the recording device and the "wind observations published by the various meteorological institutions at the present time have only a relative, but not absolute, value. It is very probable that many experiments on the relations of wind velocities to wind pressures have been made in which this anemometer correction has not been properly applied."

Professor Marvin has determined the correction to be applied to the readings of the standard form of anemometer used by the Weather Bureau. It is expressed by a logarithmic formula from which the following table taken from his report on Wind Pressures is computed:

CORRECTED WIND VELOCITIES AS INDICATED BY ROBINSON ANEMOMETER.

[Miles per hour.]

Indicated velocity.	0	1	2	3	4	5	6	7	8	9
0	......	.....	......	......	......	5.1	6.0	6.9	7.8	8.7
1	9.6	10.4	11.3	12.1	12 9	13.8	14.6	15.4	16.2	17.0
2	17.8	18.6	19.4	20.2	21.0	21.8	22.6	23.4	24.2	24.9
3	25 7	26.5	27.3	28.0	28.8	29.6	30.3	31.1	31.8	32.6
4	33.3	34.1	34.8	35.6	36.3	37.1	37.8	38.5	39.3	40.0
5	40.8	41.5	42.2	43.0	43.7	44.4	45.1	45.9	46.6	47.3
6	48.0	48.7	49.4	50.2	50.9	51.6	52.3	53.0	53.8	54.5
7	55.2	55.9	56.6	57.3	58.0	58.7	59.4	60.1	60.8	61.5
8	62.2	62.9	63.6	64.3	65.0	65.8	66.4	67.1	67.8	68.5
9	69.2	......	......	......	......	......	......	......	......	......

All observers in the United States using anemometers similar in construction to those of the Signal Service will find the values in the above table much more accurate than those commonly used.

APPENDIX C.

TORNADO STATISTICS.

The characteristics of tornadoes, the general meteorological conditions favorable to their formation, and statistics relative to their frequency, place of occurrence and essential details, have been made the subject of careful study and record by the Weather Bureau.

The reports of Lieutenant J. P. Finley, published as Professional Papers of the Signal Service No. VII and No. XVI, give the results of his researches relative to tornadoes prior to 1881, and a special study made of those occurring in the year 1884. The data for tornadoes, 1889–1896, have been recently compiled under direction of Willis L. Moore, Chief of the Weather Bureau, and are published in the annual data volume of the Bureau for 1896. These reports treat the subject in great detail, and the following facts have been abstracted from them:

The earlier records, which are necessarily incomplete, show that there were at least 580 tornadoes prior to 1881, and that of this number 505 occurred in the period of eight years, from 1874 to 1881, and 135 were unusually destructive. In the year 1884 there were 180 tornadoes. In the period of eight years, 1889–1896, there were 368 tornadoes occurring on 207 days; of these storms 24 were very destructive. "More than 90% of the property loss of the eight years fell on these 24 days. The remaining 10% was distributed throughout 183 days in which tornadoes of greater or less violence occurred. The great tornadoes of the past eight years have averaged about three per annum. Lists of very destructive storms for the 18 years previous to 1889 show an average of three per annum."

The number and the violence of tornadoes bear no definite relation to their destructive effects, as the latter are largely incidental to the place of occurrence. Of the $24 000 000 property loss by tornadoes during the past 8 years, $12 000 000 is chargeable to less than a half hour's destruction in St. Louis, Mo., and East St. Louis, Ill., on May 27th, 1896, and over $2 000 000 to the destruction in Louisville, Ky., on March 27th, 1890.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will hereafter be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

MAX JOSEPH BECKER, Past-President Am. Soc. C. E.*

DIED AUGUST 23D, 1896.

Max Joseph Becker was born at Coblenz, Germany, June 20th, 1828, and was educated in the schools of Coblenz, and at the University of Bonn.

After leaving the University, he passed the requisite examinations for admission to service on the Government Railroad surveys, and in 1848 began his professional career on the Cologne and Minden Railroad in the capacity of "engineer's apprentice" (rodman), with headquarters at Hamm, in Westphalia.

This work was interrupted by the Rebellion of 1848, and by reason of his connection therewith he was compelled to leave Germany, along with such men as Frederick Hecker, Carl Schurz, Franz Sigel, August Willich, and others, whose enforced exile has been our country's gain.

After a brief sojourn in Switzerland, he came to the United States, landing in New York in 1850. His first year's residence in this country was a struggle for a foothold, during which he tried various lines of employment, among others, making surveys in Connecticut for a map-publishing house, as draftsman in an engraving establishment, and even tried his hand at journalism on the staff of the *Abendzeitung*.

In December, 1851, he entered the service of the Steubenville and Indiana Railroad at Steubenville, Ohio, under Jacob Blickensderfer, Jr., M. Am. Soc. C. E., Chief Engineer. His first service with this company was as a draftsman, but this was soon changed to transitman on location, and then to Resident Engineer on construction, in which capacity he continued until the completion of the road in 1854.

From 1854 to 1856 he held no salaried position, doing such professional work as offered, and occupying a part of his time in making and publishing a map of Coshocton County, Ohio.

In 1856 he entered the service of the State of Ohio as Resident Engineer on the Ohio Canal, and continued in that position until 1859.

* Memoir prepared by William Metcalf, Thomas H. Johnson and Samuel Rea, Members Am. Soc. C. E.

From 1859 to 1861 he was Resident Engineer on the Marietta and Cincinnati Railroad in charge of location and construction. During this time he also rebuilt a suspension bridge over the Scioto River, at Portsmouth, Ohio, which had been destroyed by the undermining of one tower during a flood.

During the presidential campaign of 1860 Mr. Becker took a lively interest in the success of the Republican party, and made numerous speeches in German in various towns and cities of Southern Ohio, where the German element was strong. In appreciation of this Abraham Lincoln commissioned him Postmaster at Portsmouth, Ohio. But the drudgery and the red-tape methods of that office were not suited to his taste, and in 1862 he resigned the office and again took service under his former chief, Mr. Jacob Blickensderfer, Jr., at that time Chief Engineer of the Pittsburgh and Steubenville Railroad. Mr. Becker was placed in charge of construction of the Steubenville Bridge and its approaches, one of the most important structures crossing the Ohio River, and subsequently rebuilt by him.

In 1863 he again went to the Marietta and Cincinnati Railroad to take charge of the location and construction of its extension from Loveland, Ohio, to Cincinnati. His connection with this railroad company continued until 1867, when he became Chief Engineer of the Steubenville and Indiana Railroad, which position he continued to fill in the various companies formed by its consolidation with other roads until he at length had charge of the entire system of the Pittsburgh, Cincinnati, Chicago and St. Louis Railway. For nearly thirty years he not only discharged the responsible duties entrusted to him with rare fidelity and ability, but won the confidence and affection of his associates. To the professional acquirements which made his judgment of such pronounced value, he brought a long experience, a well-balanced mind and a fund of sound common sense, which were of the greatest service in the solution of the many important problems that confronted him from time to time in his railway career.

In January last the Board of Directors sought to make his declining years easier, and to that end relieved him of some of his duties, and changed his title to "Consulting Engineer and Real Estate Agent." But the disease which finally carried him off had even then laid its hand upon him, and he was not permitted to enjoy the rest from labor contemplated by this act. After a brave fight, marked by his usual cheerful serenity, he succumbed on August 23d, and the world lost a gallant, honest gentleman, who had reflected credit upon his profession and who left a name without a shadow of stain or reproach.

The above record is sufficient to show the power and character of the man, who, coming to this country a political refugee, almost unknown and nearly penniless, at once went to work ardently, at whatever his hand could find to do, to make his own living and to be

dependent upon no one. In social moments, when led to speak of his early struggles, his account was of great interest; he threw into it a strain of humor which would have made it laughable if it had not been really pathetic. No attempt of ours to repeat his tale could do it justice, because it would be impossible to reproduce his inimitable style; it is sufficient to say that his marked success and steady rise from obscurity to the highest plane of his profession, where he found himself at home, should be an enduring encouragement to all struggling young men who may sometimes, under pressure of a hard fight, get the mistaken notion into their heads that the world is against them.

Mr. Becker's professional and personal standing among engineers was of the highest; he was an honored and beloved member of the Engineers' Society of Western Pennsylvania; he was a member of its Board of Direction for many years, President for several terms, and most useful in every way.

Mr. Becker was elected a Member of the American Society of Civil Engineers on August 7th, 1872, and was made its President in 1889. At the time of his election his personal acquaintance in the Society was not very large, and some questions were asked; before his term had expired he had won all hearts, as he always did wherever he came into touch with people. Mr. Becker was more than an able engineer, he was a man of force, a gentleman, genial and witty, kind and sympathetic, always ready to lend a helping hand. A man without malice or guile, he had no time for animosities, and his memory will ever remain in the minds of all who knew him.

ROBERT NEILSON, M. Am. Soc. C. E.*

DIED OCTOBER 12TH, 1896.

On the northern shore of Lake Ontario, about 25 miles west of Kingston, is the hamlet of Sandhurst, known also as Fredericksburg, situated in Lennox County, Province of Ontario, Canada. In this place Robert Neilson was born, August 19th, 1837. His parents were Thomas and Eliza Neilson, his father's occupation being that of a farmer.

His boyhood was spent on the farm, and when he became old enough he took active part in the details and management of the work. His early education was received in the schools of his native place, and the improvement of his opportunities fitted him at the age of 19 to become a teacher. He taught in the schools of Fredericksburg from 1856 to 1858, and at the same time prepared himself for entrance to the Polytechnic Institute, at Troy, N. Y., where he began his course in the fall of 1858. He was graduated from this institution in the summer of 1861, and returned to his home intending to follow his chosen profession of civil engineering in his native country.

He made efforts to obtain employment under the Canadian government, but finding that considerable time was necessary to effect this purpose, he again found occupation in farming and as a teacher in the schools of Napanee, near his father's home. This occupied the year 1862 and part of 1863.

In October, 1863, he came to the United States and entered the service of the Pennsylvania Railroad Company as rodman on the construction of the Philadelphia and Erie Railroad, which was opened about a year later. In March, 1864, he was appointed Assistant to Mr. A. J. Cassatt, then Resident Engineer of the Middle Division of the Philadelphia and Erie Railroad between Renovo and Kane, Pa. In September, 1865, he was chosen to succeed Mr. Cassatt as Resident Engineer, and it was during his residence at Renovo that he married Elizabeth J. Wright, June 25th, 1866. His ability as an engineer was again recognized by his appointment, January 1st, 1868, to the position of Resident Engineer of the Middle Division of the main line of the Pennsylvania Railroad between Harrisburg and Altoona.

On the morning of July 17th, 1868, five spans aggregating 830 ft. of the west end of the Pennsylvania Railroad Bridge over the Susquehanna River at Rockville, about 5 miles from Harrisburg, were destroyed by fire. This was a wooden deck bridge of the usual Howe truss form. Mr. Neilson soon reached the scene of the catastrophe, and as trestling

* Memoir prepared by E. D. Nelson, Esq.

could not be well adopted, it was decided to rebuild the permanent bridge at once. It was necessary to remove the wrecked spans, to have the timber sawed and to order the rods, angle blocks and other parts and assemble them at the bridge. The material began to arrive on the third day and the work moved rapidly to completion, the bridge being opened to the passage of trains on July 28th, hardly twelve days after its partial destruction.

Many similar instances might be cited to show his quick comprehension in emergencies, his ready judgment as to the best course to pursue, and his promptness in completing the work in hand.

In January, 1870, he was promoted to the superintendency of the West Penn Division of the Pennsylvania Railroad, which position he held until his transfer, in September, 1874, to the Elmira and Canandaigua Divisions of the Northern Central Railway, as Superintendent. During his superintendency of these divisions he was obliged to take an active part in traffic matters in addition to the duties relating to engineering and transportation which usually devolve upon a railroad superintendent.

His success in all of these departments of railroad work most justly earned for him his promotion, in September, 1881, to the position of General Superintendent of the Philadelphia and Erie Railroad and the Northern Central Railway, north of Harrisburg. In January, 1883, his jurisdiction was extended over the entire line of the Northern Central from Baltimore north, and he continued in this position, as a notably successful operating officer, till the time of his death, October 12th, 1896, at his home at Williamsport, Pa.

His personal characteristics greatly endeared him to his subordinates and associates. Firm in purpose, yet always kind and considerate, he directed his subordinate officers more by his own strong personality and the evident wisdom which he possessed, than by the harsher methods of arbitrary authority; and he built up those under him with the knowledge which by his long experience and clear mind he had gained.

He never refused counsel or advice to those who asked, and he showed a personal interest in the affairs of those who sought his help, which added to the esteem in which he was held by all who came in contact with him.

In the death of Mr. Neilson the Pennsylvania Railroad Company lost one of its most efficient operating officers, and the profession an engineer of pronounced ability in railroad construction and maintenance.

Mr. Neilson was elected a Member of the American Society of Civil Engineers on February 17th, 1869.

Vol. XXIII. FEBRUARY, 1897. No. 2.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publication.

CONTENTS.

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The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—127 EAST TWENTY-THIRD STREET, NEW YORK.

Vol. XXIII. FEBRUARY, 1897. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

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CONTENTS:

REPORT IN FULL OF THE ANNUAL MEETING, JANUARY 20th AND 21st, 1897.

Wednesday, January 20th, 1897.—President Thomas Curtis Clarke in the chair; Charles Warren Hunt, Secretary. The meeting was called to order at 10.30 o'clock. Meeting called to order.

The President.—The first business before the meeting is to appoint three tellers to canvass ballots, and I will appoint Messrs. Jefferis, Burke and Brown, employees of the Society. Tellers Appointed.

Under the Constitution the polls are closed at noon and the ballots are canvassed publicly by the tellers; and in order to insure an early report, they will begin the count at once. Anyone who wishes to see the operation performed has only to walk into the adjoining room, taking good care he does not disturb the gentlemen in their business, so that they will get through by 12 o'clock. All ballots received before 12 o'clock are counted.

The next business in order is the reading of the minutes of January 6th, 1897.

Minutes of Last Meeting read and approved.

The Secretary read the minutes of the meeting of January 6th, 1897.

The PRESIDENT.—Gentlemen, you have heard these minutes read. Is it your pleasure that they be accepted? No opposition is made. They are so accepted.

The next business in order is the announcement of the Annual Meeting programme by the Secretary.

Programme

The SECRETARY.—The programme for the annual meeting as printed and distributed is to be carried out. The only point on which information is necessary is about the train, which leaves to-morrow morning, Thursday, from the Grand Central Station on the New York Central road at 9 o'clock. That time is not stated in the programme. The train must leave at 9 o'clock, and is a special train. I would like also to ask that members register on the cards provided for that purpose, either here, or at the Society House.

Report of Board of Direction read.

The PRESIDENT.—The next business in order is the Annual Report of the Board of Direction, which the Secretary will please read.

The Secretary read the report of the Board of Direction.*

The PRESIDENT.—Gentlemen, you have heard the report of the Board of Direction. It is now open for discussion. Is it your pleasure that this report be accepted?

On motion, the report was accepted.

The next business is the report of the Treasurer of the Society.

The Treasurer read his report.†

The PRESIDENT.—You have heard the report of the Treasurer. Is it your pleasure that it be accepted?

Mr. FOSTER CROWELL.—I move that it be accepted.

The motion was carried.

The PRESIDENT.—The report of the Committee on Finance is next.

The Secretary read the report of the Committee on Finance.*

The PRESIDENT.—Gentlemen, you have heard the report of the Finance Committee. Is it your pleasure that it be accepted?

Mr. CROWELL.—I move that it be accepted.

The motion was carried.

The PRESIDENT.—There is another report here of the Secretary acting as Auditor, which is printed and before you. It is simply a distribution in detail of the receipts and disbursements. Unless some one objects, the reading of this report will be omitted.

Norman Medal Report.

The next business in order is the report of the Board of Censors to award the Norman Medal.

The Secretary read the report of the Board of Censors appointed to award the Norman Medal.§

* See *Proceedings*, Vol. xxiii, p. 9.

† See *Proceedings*, Vol. xxiii, p. 16.

‡ See *Proceedings*, Vol. xxiii, p. 24.

§ See *Proceedings*, Vol. xxiii, p. 3.

Rowland Prize Report.

The President.—Gentlemen, you have heard the report. The next report is from the Committee to award the Rowland Prize.

The Secretary read the report of this Committee.*

Report on Time and Place for Convention.

The President.—The next report is that of the canvass of ballots received for the place of holding the next Annual Convention.

The Secretary.—Two hundred and seventy votes have been received for the place at which to hold the next Annual Convention, distributed as follows:

Quebec	29	Niagara Falls	7
New York	24	Baltimore	6
Chicago	21	Buffalo	6
Pittsburg	15	Duluth	6
Washington	13	Nashville	5
Philadelphia	12	Cincinnati	4
Saratoga	12	Mexico	4
Detroit	9	Great Lakes	3
Denver	9	Atlantic City	3
Montreal	9	Mackinac Island	3
Boston	8	Cleveland	3
St. Louis	7	Lake George	3
New Orleans	7	Sault Ste. Marie	3

The remaining votes were scattering.

The Secretary read the following letter:

January 15th, 1897.

Charles Warren Hunt, Esq.,
Secretary, American Society of Civil Engineers,
127 East Twenty-third Street, New York, N. Y.

Dear Sir,—As I remember, a short time ago members were asked to suggest a place for the next Annual Convention of the Society.

I suggest as a proper place Mackinac Island. I have not made a study of all the advantages and disadvantages, but it occurs to me, off-hand, that there are a great many advantages in its favor as a place for a society convention. The hotel accommodations are ample. The nearness of the Sault, say 50 miles distant, which place can be reached by boat from Mackinac, making a delightful excursion, is one of the chief advantages I have in mind because of the great engineering works there, recently completed; in fact I do not now think of any recent engineering work that would be more interesting than the great canal locks at the Sault. I understand that there is sufficient accommodation at the Sault for the Society. The New York party could make the trip *via* any of the roads to Buffalo, and from there on the "Northwest" or "Northland" to the Sault. Owing to the consideration last year of a trip by the Society on these steamers, I presume you are familiar with the accommodations.

Respectfully,
C. G. Force.

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* See *Proceedings*, Vol. xxiii, p. 3.

Correspondence on Time and Place for Convention.

The Secretary read the following letter from the Engineering Association of the South:

HEADQUARTERS, ENGINEERING ASSOCIATION OF THE SOUTH,
NASHVILLE, TENN., January 15th, 1897.

CHARLES WARREN HUNT, Esq., *Secretary*,
127 East Twenty-third Street, New York City.

Dear Sir,—At the regular monthly meeting of this Association, held at Headquarters yesterday evening, the following resolutions were passed:

"*Resolved*, That this Association invites the American Society of Civil Engineers to hold its meeting of 1897 in the City of Nashville.

"*Resolved*, Further, that the Secretary be instructed to at once communicate this invitation to the Secretary of the American Society of Civil Engineers."

In pursuance of these instructions I have the honor to communicate to you this action of our Association, and to say, further, that the members of this Association will do all in their power to make the visit of the American Society of Civil Engineers to Nashville pleasant and profitable.

Trusting to hear from your Association a favorable reply, I am,

Truly yours,
LUCIUS P. BROWN,
Secretary.

The SECRETARY.—I have also from Nashville letters from the Governor of Tennessee, the Nashville Chamber of Commerce, the Chairman of the Board of Public Works, the City Council, the three newspapers, and the Director-General of the Tennessee Centennial.

The PRESIDENT.—Gentlemen, this question of the place of holding the next Annual Meeting is now open for discussion. What is your pleasure?

Mr. CROWELL.—I move that it be referred to the Board of Direction with power.

The motion was carried.

The PRESIDENT.—The next business in order is the reading of the reports of special committees. There are none, but the Secretary has received a letter from Dr. Charles B. Dudley, Chairman of the Sub-Committee on the Analysis of Iron and Steel, which he will please read.

Report of Committee on Analysis of Iron and Steel.

The Secretary read the following letter:

ALTOONA, PA., January 15th, 1897.

Mr. CHAS. WARREN HUNT,
Secretary, American Society of Civil Engineers,
127 East Twenty-third Street, New York City.

Dear Sir,—You are not more disappointed in regard to the report of the Committee on Standard Methods for the Analysis of Iron and Steel than I am. When the history of the work of this Committee comes to be written, I think everybody will be astonished at the amount of work that has been done, and the difficulties which have been met, in trying to establish a standard method. Two or three times we thought we were completely out of the woods, and that every-

thing was in first-rate condition, and on a little wider experience, some new difficulty would arise, that has made additional work necessary.

I fear it will be impossible for me to be at the meeting January 20th, as I must give a lecture at the Franklin Institute, Philadelphia, on the 22d of January, and it will take all the time I have to get ready for that.

I wish you would announce to the meeting the purport of this letter, and that, of course, while the Committee cannot devote all their time to this matter, surely not a week passes that some work is not done on doubtful points, all of which is leading toward the desired end. I think I may safely say now that unless some new and entirely unexpected difficulty arises, we will be able to make a report in the course of a month or six weeks.

Very truly yours,

CHAS. B. DUDLEY,
Chairman Sub-Committee.

The SECRETARY.—Mr. George M. Bond, Chairman of the Committee on Units of Measurement, had also expected to have a meeting of that committee this morning. They have been unable to get together to make any definite report, and he asked me to say they were working on the report and hoped to have one ready for the next convention. Report of Committee on Units of Measurement.

The PRESIDENT.—The next business in order is the report of the Board of Direction in the matter of the appointment of a special committee of the Society on the proper manipulation of tests of cement. Report of Board of Direction on Appointment of Special Committee on Manipulation of Tests of Cement.

The Secretary read the report.*

The PRESIDENT.—The clause of the Constitution which bears upon the reception of this report is as follows :

"Special committees to report upon engineering subjects shall be authorized only by a majority of the votes cast by the Society, and in the following manner: A proposition to appoint such a committee shall be presented at a regular meeting of the Society, and if sustained, on a motion to refer the same to the Board of Direction, by an affirmative vote of not less than 25 Corporate Members, it shall be so referred.

"The Board of Direction shall then consider the same and report its recommendations to the Society at the next general business meeting, together with a statement of the arguments for and against the appointment of such Committee."

This report has now reached that stage. This is the next regular Business Meeting. The Constitution then goes on to say:

"If a motion for the issue of a letter ballot thereon receive the affirmative vote of two-thirds of the Corporate Members present, the Board of Direction shall, within thirty days thereafter, issue the letter ballot, accompanied by a statement of the arguments for and against the proposition.

"A majority of a total vote of not less than one-third of the corporate membership of the Society shall be necessary for its adoption, whereupon the Committee so authorized shall be appointed by the Board of Direction."

* See *Proceedings*, Vol. xxiii, p. 4.

Discussion on Appointment of Special Committee on Manipulation of Tests of Cement.

This report is now open for discussion.

Mr. EDWARD P. NORTH.—I move that the report be adopted.

Mr. CROWELL.—I would suggest to the mover of the motion that the motion carry with it the direction to have the matter proceed to a ballot.

Mr. NORTH.—I supposed that would be done in the adoption of the report. I move that the report be adopted and the matter proceed to a letter ballot.

Mr. CROWELL.—I second the motion.

The PRESIDENT.—As there appears to be no discussion, I will put the question——

Mr. ROBERT W. LESLEY.—In connection with that report, while I do not want to oppose it, I want to say one thing. It seems there has been a very intelligent consideration of the subject by the Board. As I understand the report, it does not relate to any change in the specification—merely a change in the methods of manipulation. The only thought I desire to throw out in that direction is in respect to one paragraph of the report, and that is as to the ability to make tests of cement similar to tests of metal. The difficulty in that connection is one I will take only a few moments to call your attention to.

In the first place, all tests of metal are made of the metal as it is produced at the works. All tests of cement are made of the material after it leaves the works and by people other than the manufacturer. In the next place, the total product of cement in the country last year would aggregate about 12 000 000 barrels, which, by the figures of the Bureau of Statistics and the figures of the geological reports, showed about $9 000 000 worth of material. The point that I want to direct your attention to particularly is that if any method of testing is adopted whereby the present modes are to amplified and not simplified, the result will be to throw into testing laboratories of a scientific character a large volume of business which, under the circumstances of the case, as the materials arrive on the work, must be done at the work by the engineers and people working under their direction. In other words, while the testing of metals as related to the cost of metals is from 1 to 2%, and sometimes as low as 0.1% on iron and steel, the price of testing cement in laboratories, taking the ordinary Rosendale and Portland cement, is 20% on the total value of the material at the work. In other words, if the Committee consider this in the line of an amplification of the present simple methods, the result will be that the manufacturers of cement will have to charge 20% more on all their materials, or the consumer will have to pay that, in which case the manufacturer will have 20% of his cost outside of his method of manufacturing. He will have to deal with laboratories instead of dealing with the problems of his business. It is to that large discrepancy between the cost of testing

iron, steel and other metal, where the value is great and the cost of testing cement, where the value is small, that I desire to call the attention of this Society; so that in the appointment of the committee, and the consideration of the subject by the committee, the consideration be rather directed to the simplification of tests, that this material can be tested upon the work.

It is perfectly true that it may be argued a certificate from a testing laboratory is an insurance, but in the insuring under the present specifications has there been a failure of work to the extent of 20 per cent? Is not that a large insurance to pay for a matter of this kind? These remarks are offered not in opposition to this report, but merely to direct the attention of those who may be on that Committee, and the Society at large, to the particular difference between the testing of metals and the testing of cements.

Mr. North.—In regard to the remarks of the gentleman who has just sat down, the person who is responsible for work should have any insurance that he thinks necessary. For instance, in the course of the last season, I found, in June, cement offered to us testing between 40 and 60 lbs. I told the manufacturer what his cement was testing at, and in three months he ran it up between 70 and 160 lbs. Now whatever the cost of testing that cement may have been, every one will see that we have a cement which was better than what we started out with, so that, according to this one instance, we were justified in spending 50% of the cost of the cement if we were to keep on using it and testing it.

Mr. S. Whinery.—The questions which have been discussed probably will come before that committee if appointed, and gentlemen who have views to express along that line will, of course, communicate with the committee if it shall be appointed. I think there can be no question but that the method recommended by the former committee of the American Society ought to be revised. We have had a large amount of experience since that in the testing of cement. It has been shown in practice that tests made presumably in conformity with those recommendations vary very widely. Now the question is, can we not adopt some standard method of testing cement which in the hands of different people will give approximately reliable and the same results? As the report of the Board states, the Society has already, to a certain extent, committed itself to a method of testing cement; that method has been found to be somewhat old-fashioned—out of date. It needs revision. Now, it seems to me, as the report recommends that the Society should do one of two things—either appoint a committee to revise this method of testing cement——

The President.—I beg your pardon. Would you allow me to read the resolution? It is to recommend to the Board of Direction the consideration of the appointment of a committee to report on the proper

Discussion on Appointment of Special Committee on Manipulation of Tests of Cement.

manipulation of tests of cement, not to have anything to do with fixing what the tests are, the amount that the cement shall bear, or the number of pounds it shall stand, but the proper manipulation. That is the question before the meeting.

Mr. Whinery.—Thank you, Mr. President. That is the way I understood it, if I expressed it another way. I think it is due the Society that either this method of manipulation recommended by the committee should be revised by another committee and brought up to date of engineering practice at the time, or that the previous action should be revoked. I am very heartily in favor of the appointment of this committee. When this committee is appointed it will doubtless consider all the questions that are raised in regard to methods of testing cement and manipulation, and those questions can be considered at the time.

Ballot Ordered on Appointment of Special Committee on Manipulation of Tests of Cement.

The President.—Gentlemen, are you ready for the question? The question is whether this business meeting shall recommend the appointment of a committee to report on the proper manipulation of tests of cement, and that the same shall be submitted to the Society by letter ballot.

The motion was carried unanimously.

Resolution Presented from S. C. Thompson.

The President.—It is now in order for any member to present any resolutions that he pleases.

The Secretary.—I have a letter from Mr. S. C. Thompson, Member of the Society, dated January 17th.

The Secretary presented a preamble and resolution* from S. C. Thompson, M. Am. Soc. C. E.

The President.—Gentlemen, we have now 50 minutes before the polls can be lawfully declared closed. This resolution of Mr. Thompson's opens a very wide field of discussion, and I hope you will be able to employ the 50 minutes.

Mr. John Thomson.—May I ask the name of the maker of that resolution?

The Secretary.—Mr. S. C. Thompson.

Mr. Theodore Cooper.—I move that the resolution be received and laid on the table.

The motion to lay on the table was carried.

The President.—Does anybody wish to offer any resolutions at this time?

The tellers report that they will be through with the counting of the ballots by the legal time of closing the polls at 12 o'clock. Therefore it is in order to have a recess of the Society now, to meet again at 12 o'clock, if you so wish. If somebody will move a resolution, I will put it.

On motion, a recess was taken until 12 o'clock.

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* See *Proceedings*, Vol. xxiii, p. 6.

(After recess.)

The PRESIDENT.—The hour of 12 o'clock having now arrived, I do hereby declare the ballot closed. The Secretary will please read the report of tellers.

The Secretary read the report of tellers.*

Report of Tellers Read.

The PRESIDENT.—Gentlemen, you have heard the report of the tellers, and I declare these gentlemen to be elected officers of the Society.

I shall not detain you with many words. But I wish to say on leaving this chair that I entered it under a misconception. I was told it was a chair which imposed upon its occupant very onerous duties. I find I was entirely wrong. The executive business of the Society has been well conducted by its committees, who have punctually attended at the meetings and have there performed their duties faithfully and with energy, assisted by our Secretary, whose executive ability is well known to you, so that it has left really very little for the President to do in the way of the performance of the details of executive duty. In fact there are but two things that he is absolutely obliged to do, and those are the signing of diplomas and the signing of necessary legal papers. The Society I leave in excellent condition. We have no domestic or foreign quarrels, as the President of the United States is apt to say. The practical business has been the preparing and putting under construction of the new house, and when that house is finished, and the old house which we have now is sold at the valuation of experts, after paying the interest charges and the current expenses of the new house, which, of course, will be larger than those of the present one, we shall still have a surplus. I think I may say that there is no other society or association in New York or in the United States of which a better report can be given than that.

Major Harrod, though you need no introduction to this Society, it is my pleasant duty to ask you to assume this Chair, which I now vacate for you.

Mr. Harrod, President, Introduced.

The President-elect took the chair and said:

I am very deeply sensible of the honor that the Society has conferred upon me. I assume the duties of the office with hope and courage after the description our President has given of the machinery and executive work of the Society, simply promising that to such duties as devolve upon me I shall take great pride and pleasure in giving my very best energy and attention.

There is no further regular business before the meeting, but any business that any member may have to present is now in order.

If there is none, the Secretary will make his announcements.

The SECRETARY.—I have only one thing to announce, Mr. President, and that is, there will be a meeting of the Board of Direction, as required by the Constitution, at 2.30 this afternoon in the Society House.

Adjourned.

Final Adjournment.

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* See *Proceedings*, Vol. xxiii, p. 6.

Wednesday evening, 20 o'clock.—The Secretary delivered an address, illustrated by lantern slides, on the history of the Society.

Thursday, January 21st, 1897.—At 9 o'clock a special train on the New York Central and Hudson River Railroad, provided through the courtesy of John M. Toucey, F. Am. Soc. C. E., General Manager, carried a party of about 200 members and guests to Croton Landing. From that place the party was taken by stages to the New Croton Dam. After an inspection of this interesting work, made by invitation of A. Fteley, M. Am. Soc. C. E., Chief Engineer Croton Aqueduct Commission, the party returned to Croton, to the Kitchawan House, where luncheon was served. On the return trip to New York, the train ran over the new four-track draw-bridge and elevated Park Avenue tracks, being the first train to make the trip.

A reception was held at the Waldorf at 20 o'clock, which was attended by 185 members and guests.

The names of 279 members of various grades in attendance at the Annual Meeting, excursion and reception is given below. The list is, however, incomplete on account of the failure of a number of members to register.

J. L. Adams.........Brooklyn, N. Y.
C. H. Allen..........New York City.
J. P. Anderson........Trenton, N. J.
Horace Andrews.......Albany, N. Y.

John W. Bacon......Danbury, Conn.
William Henry Baldwin, Yonkers, N. Y.
J. L. Bauer..........New York City.
George Baum.......Brooklyn, N. Y.
Charles J. Bates......New York City.
Arthur Beardsley, Swarthmore College, Pa.
W. E. Belknap .....Brooklyn, N. Y.
Edwin J. Beugler..Bridgeport, Conn.
Walter G. Berg .....New York City.
William D. Bigelow..New York City.
George H. Bishop, Middletown, Conn.
H. Bissell........W. Medford, Mass.
Clarence Blakeslee, New Haven, Conn.
John Bogart ....New York City.
Alfred P. Boller......New York City.
C. M. Bolton......Washington, D. C.
George M. Bond.....Hartford, Conn.
L. B. Bonnett.......Elizabeth, N. J.
Adolphus Bonzano.Philadelphia, Pa.
William F. Booth, Poughkeepsie, N. Y.
A. L. Bowman.......New York City.
G. W. Bramwell......New York City.
W. H. Breithaupt....New York City.
P. F. Brendlinger..Philadelphia, Pa.
J. Breuchaud ....Yonkers, N. Y.
Josiah A. Briggs.....New York City.
H. W. Brinckerhoff..New York City.
Fred Brooks.......... Boston, Mass.
Charles W. Buchholz.New York City.
G. B. Burbank.......New York City.
J. A. Burden........New York City.
H. D. Bush.......Springfield, Mass.

Albert Carr.......East Orange, N. J.
H. A. Carson..........Boston, Mass.
Robert Cartwright...Rochester, N. Y.
W. A. Cattell..Long Island City, N. Y.
Chas. F. Chase.....Providence, R. I.

Samuel H. Chittenden, Saratoga, N. Y.
G. L. Christian.......Yonkers, N. Y.
G. L. Christy........New York City.
L. Russell Clapp ....New York City.
George Hallett Clark, New York City.
L. V. Clark, Jr. ....Philadelphia, Pa.
T. C. Clarke.........New York City.
Edwark B. Codwise..Kingston, N. Y.
Amory Coffin........New York City.
F. C. Coffin ....Boston, Mass.
Mendes Cohen.......Baltimore, Md.
F. Collingwood......Elizabeth, N. J.
C. B. Comstock.,.....New York City.
E. H. Connor ......Rock Island, Ill.
Casimir Constable....New York City.
Howard Constable....New York City.
S. L. Cooper.........Yonkers, N. Y.
Theodore Cooper....New York City.
W. H. Coverdale. ....Pittsburg, Pa.
W. P. Craighill.Charlestown, W. Va.
Albert S. Crane......Brooklyn, N. Y.
Alfred Craven ...Kingsbridge, N. Y.
W. W. Crehore.......New York City.
R. Walter Creuzbaur, New York City.
J. J. R. Croes ... ...New York City.
Benjamin L. Crosby...St. Louis, Mo.
Foster Crowell........New York City
A. C. Cunningham... .Albany, N. Y.
F. S. Curtis. .....New Haven, Conn.

A. P. Davis.......Washington, D. C.
Joseph P. Davis......New York City.
E. P. Dawley.......Providence, R. I.
Jno. Sterling Deans.Phœnixville, Pa.
Emilio Del Monte....New York City.
S. L. F. Deyo ....New York City.
Albert B. Drake..New Bedford, Mass.
James Duane ....New York City.

N. M. Edwards.......Appleton, Wis.
C. C. Elwell.........Norwich, Conn.
Charles E. Emery....New York City.
Oscar Erlandsen.....New York City.
M. E. Evans........New York City.

John F. Fairchild,
Mount Vernon, N. Y.
H. H. Farnum......New York City.
B. R. Felton..........Boston, Mass.
H. C. Felton..........Camden, N. J.
J. W. Ferguson......Paterson, N. J.
Clark Fisher..........Trenton, N. J.
F. D. Fisher.........Brooklyn, N. Y.
Andrew Ernest Foyé.New York City.
George B. Francis.....Boston, Mass.
J. R. Freeman ....Providence, R. I.
A. H. French.......Brookline, Mass.
Walter Frick........Carbondale, Pa.
G. H. Frost..........New York City.
A. Fteley.............New York City.
J. H. Fuertes.........New York City.
F. L. Fuller...........Boston, Mass.

Charles Gartensteig...New York City.
Charles W. Gay.........Lynn, Mass.
Martin Gay..........New York City.
H. M. Geer...........Ballston, N. Y.
George E. Gifford .. New York City.
Charles E. Goad.......Toronto, Ont.
J. M. Goodell........Brooklyn, N. Y.
E. Sherman Gould....Yonkers, N. Y.
Charles S. Gowen...Sing Sing, N. Y.
C. H. Graham...New Rochelle, N. Y.
Edwin D Graves....Hartford, Conn.
William Gray........ .Carmel, N. Y.
B. R. Green......Washington, D. C.
Francis C. Green.....New York City.
Howard B. Green.Penn Grove, N. J.
D. M. Greene............Troy, N. Y.
G. S. Greene, Jr .....New York City.
J. N. Greene..............Calais, Me.
J. E. Greiner.........Baltimore, Md.

Stephen S. Haight....New York City.
George R. Hardy..New Haven, Conn.
J. H. Harlow..........Pittsburg, Pa.
C. M. Harris.........New York City.
Benjamin M. Harrod,
New Orleans, La.
Henry Hartwell......Johnstown, Pa.
W. J. Haskins.......New York City.
Arthur Haviland.....New York City.
A. McL. Hawks .....Tacoma, Wash.
Charles W. Hazelton,
Turner's Falls, Mass.
Allen Hazen...........Boston, Mass.
D. W. Hemming.....New York City.
Clemens Herschel....New York City.

H. A. Hickok..........Newark, N. J.
J. W. Hill............Cincinnati, O.
S. W. Hoag..........New York City.
Thomas O. Horton......Chicago, Ill.
J. T. N. Hoyt.... ...New York City.
Charles Warren Hunt,
New York City.
William R. Hutton...New York City.

Arthur Stanley Ives..Brooklyn, N. Y.

W. H. Jacques.......New York City.
A. L. Johnston.......Richmond, Va.
George A. Just.......New York City.

Alexander E. Kastl..Northboro, Mass.
Walter Katté.........New York City.
C. W. Kelly......New Haven, Conn.
G. H. Kimball ....Cleveland, O.
J. M. Knap..........New York City.
Louis H. Knapp.......Buffalo, N. Y.
E. Kuichling.......Rochester, N. Y.

H. A. La Chicotte....New York City.
Frank P. Lant........New York City.
W. B. Lee.......... ...Hillburn, N. Y.
Eugene Lentilhon....New York City.
R. W. Lesley.......Philadelphia, Pa.
M. Lewinson.........New York City.
G. Lindenthal........New York City.
Horace Loomis.......New York City.
M. Lorini............Yonkers, N. Y.
G. E. Low.... ....Brooklyn, N. Y
Oscar Lowinson......New York City.
E. W. Van C. Lucas,
Willets Point, N. Y.

W. W. Maclay.....Glens Falls, N. Y.
Henry Manley.........Boston, Mass.
W. M. Marple..........Scranton, Pa.
O. J. Marstrand......New York City.
Wisner B. Martin......Newark, N. J.
T. H. McCann.......New York City.
D. E. McComb....Washington, D. C.
Walter McCulloh.Niagara Falls, N. Y.
James C. McGuire....New York City.
J. E. McKay.........New York City.
T. H. McKenzie......Hartford, Conn.
Alex. Rice McKim....New York City.

T. J. McMinn ....New York City.
Henry C. Meyer .....New York City.
H. A. Miller..........Clinton, Mass.
R. P. Miller.........New York City.
S. B. Miller..........New York City.
Peter Milne.........Brooklyn, N. Y.
L. G. Montony.........Cleveland, O.
E. C. Moore.........Brooklyn, N. Y.
W. Harley Moore..New Haven, Conn.
A. Mordecai...........Cleveland, O.
Mace Moulton.....Springfield, Mass.
C. H. Myers.........Brooklyn, N. Y.

R. E. Neumeyer.....Bethlehem, Pa.
O. F. Nichols.... ...Brooklyn, N. Y.
E. P. North..........New York City.
G. A. Noska..........New York City.

W. C. Oastler........New York City,
F. S. Odell........Mt. Vernon, N. Y.
L. F. Olney..........Mahwah, N. J.
S. B. Opdyke, Jr...Philadelphia, Pa.
John F. O'Rourke...New York City.

A. B. Paine.......Ballston Spa, N. Y.
A. McC. Parker......New York City.
William T. Pierce.....Boston, Mass.
J. M. Porter.............Easton, Pa.
Alexander Potter.....New York City.
F. C. Prindle........New York City.
H. G. Prout..........New York City.

George W. Rafter...Rochester, N. Y.
William G. Raymond....Troy, N. Y.
Benjamin Reece........Chicago, Ill.
J. V. W. Reynders......Steelton, Pa.
T. F. Richardson.....Clinton, Mass.
Palmer C. Ricketts.......Troy, N. Y.
E. P. Roberts........New York City.
Percival Roberts, Jr.Philadelphia, Pa.
William Roberts.....Waltham, Mass.
J. C. L. Rogge.......New York City.
F. Rosenberg.........Brooklyn, N. Y.

A. H. Sabin........Long Island City.
A. A. Schenck........New York City.
C. C. Schneider........Pencoyd, Pa.
Henry B. Seaman....New York City.
Ira A. Shaler.........New York City.

M. R. Sherrerd........Newark, N. J.
G. F. Simpson...Niagara Falls, N. Y.
Frank W. Skinner....New York City.
R. I. Sloan.......Asbury Park, N. J.
C. W. Smith..........New York City.
E. R. Smith..............Islip, N. Y.
J. S. Smith.........Cave Spring, Ga.
J. Waldo Smith......Montclair, N. J.
Merritt H. Smith.... New York City.
Oberlin Smith .....Bridgeton, N. J.
E. Gybbon Spilsbury..Trenton, N. J.
D. McC. Stauffer.....New York City.
F. P. Stearns..........Boston, Mass.
Herbert Steward. ...New York City.
J. M. Stewart ......New York City.
J. H. Stewart........New York City.
Charles F. Stowell.....Albany, N. Y.
George F. Swain. .....Boston, Mass.

J. G. Tait....... .. Stillwater, N. Y.
Lucian A. Taylor......Boston, Mass.
G. O. Tenney ...Spartanburgh, S. C.
S. C. Thompson......New York City.
G. H. Thomson......New York City.
John Thomson.......New York City.
T. Kennard Thomson.Stamford, Conn.
G. C. Tingley......Providence, R. I.
S. E. Tinkham........Boston, Mass.
G. M. Tompson.....Wakefield, Mass.
E.E. Russell Tratman.New York City.
J. C. Trautwine, Jr.Philadelphia, Pa.
Warren B. Travell....New York City.
Lee Treadwell......... Pencoyd, Pa.
Louis L. Tribus......New York City.
W. G. Triest.........New York City.
A. W. Trotter. ......New York City.
E. K. Turner...........Boston, Mass.
Gustave R. Tuska ...New York City.
A. H. Tyson ....New York City.

John D. Van Buren.Newburgh, N. Y.
I. M. Varona........Brooklyn, N. Y.
John G. Van Horne..New York City.
G. H. Vedeler........New York City.
M. A. Vielé..........Katonah, N. Y.

J. W. Walker..........Pittsburg, Pa.
C. D. Ward..........New York City.
J. F. Ward ....New York City.
L. B. Ward ....Jersey City, N. J.
R. W. Ware.........Plainfield, N. J.
Frank S. Washburn..New York City.
F. W. Watkins.........Carmel, N. Y.
Albert L. Webster....New York City.
E. Wegmann.........Katonah, N. Y.
C. E. Wells.........Northboro, Mass.
Joseph A. Wells......New York City.
N. J. Welton.......Waterbury, Conn.
S. Whinery............Cincinnati, O.
F. O. Whitney.........Boston, Mass.
William H. Wiley.....New York City.
W. J. Wilgus.......Watertown, N. Y.
J. K. Wilkes....New Rochelle, N. Y.
George S. Wilkins ..Mt. Holly, N. J.
C. J. H. Woodbury.....Boston, Mass.

H. W. York..........New York City.

MINUTES OF MEETINGS.

OF THE SOCIETY.

February 3d, 1897.—The meeting was called to order at 20.15 o'clock, Vice-President William Rich Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 74 members and 10 visitors.

Minutes of the meeting of January 20th, 1897, were approved as printed in *Proceedings* for January, 1897.

A paper by John F. Wallace, M. Am. Soc. C. E., entitled "The Substitution of Electricity for Steam as a Motive Power for Suburban

Traffic," was presented in abstract by the Secretary, who also read communications on the subject from Charles Henry Davis, M. Am. Soc. C. E., and Edward Barrington, Esq. The paper was discussed by Messrs. T. C. Clarke, Henry G. Prout, Charles E. Emery, C. J. Bates, Cary T. Hutchinson, E. D. Knap, and W. H. Knight.

Ballots were canvassed and the following candidates declared elected:

As Members.

Montague Sylvester Hasie, Fort Worth, Tex.
August Gustave Kleinbeck, Litchfield, Ill.
Trevor McClurg Leutzé, Albany, N. Y.
Harry De Berkeley Parsons, New York City.
Edward Gilbert Williams, Nombre de Dios, Republic of Colombia.

As Associate Members.

Cyrus Cates Babb, Washington, D. C.
Frederick William Cohen, Suspension Bridge, N. Y.
Duncan Lee Despard, Washington, D. C.
George Travilla Macnab, New York City.
John King MacDonald, Dunkirk, N. Y.
Burdett Moody, Lead, S. D.
Mason Delano Pratt, Steelton, Pa.
William Ulysses Scott, New Orleans, La.
Clarence Randell Van Buskirk, Brooklyn, N. Y.
DeForest Augustus Wheelock, Warren, Pa.

The Secretary announced the election by the Board of Direction on February 3d, 1897, of the following candidates:

As Juniors.

Frederick Anderson Burdett, New York City.
George Gill Honness, Newark, N. J.
Edward Ira Marvell, Fall River, Mass.
Jerre Turner Richards, Oak Park, Ill.
Joseph Springer Swindells, Brooklyn, N. Y.
James Warren Thayer, New York City.
Edward DeVoe Tompkins, Athens, Pa.
George Scherzer Walsh, Santa Ana, Salvador, C. A.
Robert Patterson Woods, Wabash, Ind.

Adjourned.

February 17th, 1897.—The meeting was called to order at 20 o'clock, Vice-President William Rich Hutton in the chair; John M. Goodell acting as Secretary, and present, also, 96 members and 18 guests.

A paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled, "A Study in the Designing and Construction of Elevated Railroads, with Special Reference to the Northwestern Elevated Railroad and the Union Loop Elevated Railroad of Chicago, Ill.," was presented in abstract by Mr. Goodell, who also read correspondence on the subject from Messrs. W. M. Hall, G. Bouscaren, W. A. Pratt, C. E. Fowler, J. C. Ostrup, C. E. H. Campbell, A. A. Trocon, F. C. Osborn, H. H. Rousseau, O. E. Mogensen, H. E. Horton, A. A. Stuart and William Barclay Parsons. The subject was further discussed by Messrs. Henry B. Seaman, T. C. Clarke, O. F. Nichols, A. P. Boller and W. W. Crehore.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 20th, 1897.—Fourteen members present.

Standing committees were appointed as follows:

Finance Committee.—Horace See, Chairman; Wm. Barclay Parsons, F. S. Curtis, John R. Freeman, and James Owen.

Publication Committee.—John Thomson, Chairman; Robert Cartwright, Rudolph Hering, John F. Wallace, and Henry S. Haines.

Library Committee.—Augustus Mordecai, Chairman; Daniel Bontecou, Chas. Warren Hunt, Wm. Barclay Parsons, and Henry G. Morse.

Other special committees of the Board were appointed.

Adjourned to February 2d, 1897.

February 2d, 1897.—Five members present.

Chas. Warren Hunt was appointed Auditor of the Society.

It was voted to hold the next Annual Convention at Quebec, Ontario, Canada, and Messrs. Peterson, Owen and Hunt were appointed a committee to fix its time and take charge of the arrangements for it.

The resignation of Thomas Harrold, Jun. Am. Soc. C. E., was accepted.

Nine candidates for admission as Juniors were elected.

Adjourned.

ANNOUNCEMENTS.

HISTORICAL SKETCH OF THE SOCIETY.

The sketch of the history of the Society, written by the Secretary, which has been printed by order of the Board of Direction, is now ready for distribution. It is illustrated with a nearly complete set of portraits of officers of the Society, has been printed in the best manner, and is bound in full morocco. It will be sold only on subscription at $10 per copy, and members are requested to send in their orders at as early a date as possible. The profit from the sale of the book will be devoted entirely to the New Society House Fund, and the publication is intended to provide a way by which every person connected with the Society may make a small contribution toward defraying the cost of the new building, and at the same time obtain a volume which, it is believed, will prove of interest to him as an engineer.

MEETINGS.

Wednesday, March 3d, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Julius Baier, Assoc. M. Am. Soc. C. E., entitled, "Wind Pressures in the St. Louis Tornado," will be presented. It was printed in *Proceedings* for January, 1897.

Wednesday, March 17th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Eugene R. Smith, Jun. Am. Soc. C. E., entitled, "The Compressibility of Salt Marsh Under the Weight of Earth Fill," will be presented. It is printed in this number of *Proceedings.*

Wednesday, April 7th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Andreas Lundteigen, Esq., entitled, "Notes on Portland Cement Concrete," will be presented. It is printed in this number of *Proceedings.*

DISCUSSIONS.

Discussion on the paper by John F. Wallace, M. Am. Soc. C. E., entitled, "The Substitution of Electricity for Steam as a Motive Power for Suburban Traffic," which was presented at the meeting of February 3d, 1897, will be closed March 15th, 1897.

Discussion on the paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled, "A Study in the Designing and Construction of Elevated Railroads, with Special Reference to the Northwestern Elevated Railroad and the Union Loop Elevated Railroad of Chicago, Ill.," which was presented at the meeting of February 17th, 1897, will be closed April 1st.

A GREETING FROM FRANCE.

The following telegram, dated Paris, January 20th, 1897, has been received:

"The French civil engineers who visited the World's Fair, at reunion, send their best wishes to friends in America."

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.		Date of Membership.
FRYE, ALBERT IRVIN	79 Chandler St., Boston, Mass.	Dec. 2, 1896
HASIE, MONTAGUE SYLVESTER	Fort Worth, Tex.	Feb. 3, 1897
KLEINBECK, AUGUST GUSTAVE	Gen. Mgr., Litchfield Mining and Power Co., Litchfield, Ill.	Feb. 3, 1897
LEUTZÉ, TREVOR McCLURG	200 Clinton Ave., Albany, N. Y.	Feb. 3, 1897
PARSONS, HARRY DE BERKELEY	(Consulting Engineer and Professor of Steam Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.), 22 William St., New York City.	Feb. 3, 1897

ASSOCIATE MEMBERS.

BABB, CYRUS CATES	Asst. Hydrographer and Inspector of Hydrographic Stations, U.S. Geological Survey, Washington, D. C.	Jun. Assoc. M.	Feb. 2, 1892 Feb. 3, 1897
COHEN, FREDERICK WILLIAM	P. O. Box 586, Suspension Bridge, N. Y.		Feb. 3, 1897
DESPARD, DUNCAN LEE	(Mackall & Despard), 1405 F St., N.W., Washington, D. C.		Feb. 3, 1897
MACNAB, GEORGE TRAVILLA	(Dept. of Street Impts., 23d and 24th Wards), 104 West 130th St., New York City.		Feb. 3, 1897
MACDONALD, JOHN KING	City Engineer, Dunkirk, N. Y.		Feb. 3, 1897
NEWBERRY, SPENCER BAIRD	Gen. Mgr. Sandusky Portland Cement Co., Sandusky, Ohio		Jan. 6, 1897
PRATT, MASON DELANO	St. Ry. Eng., Penna Steel Co., Steelton, Pa.	Jun. Assoc. M.	Sept. 5, 1888 Feb. 3, 1897
VAN BUSKIRK, CLARENCE RANDELL	(Dept. City Works), Van Sicklen St. and Kings Highway, Brooklyn, N. Y.		Feb. 3, 1897
WHEELOCK, DE FOREST AUGUSTUS	City Engineer, Warren, Pa.		Feb. 3, 1897

JUNIORS.		Date of Membership.
BURDETT, FREDERICK ANDERSON	Post & McCord, 289 Fourth Ave., New York City	Feb. 2, 1897
HONNESS, GEORGE GILL	285 Belleville Ave., Newark, N. J.	Feb. 2, 1897
MARVELL, EDWARD IRA	81 Bedford St., Fall River, Mass.	Feb. 2, 1897
RICHARDS, JERRE TURNER	115 Kalos St., Wissahickon, Philadelphia, Pa.	Feb. 2, 1897
THAYER, JAMES WARREN	Care of White-Crosby Co., 29 Broadway, New York City.	Feb. 2, 1897
TOMPKINS, EDWARD DE VOE	Hotel Stimson, Athens, Pa.	Feb. 2, 1897
WOODS, ROBERT PATTERSON	City Engineer, Wabash, Ind.	Feb. 2, 1897

CHANGES AND CORRECTIONS.

MEMBERS.

ANDERSON, LATHAM.................Kuttawa, Lyon Co., Ky.
AYRES, HENRY WILCOX..............Board of Water Commissioners, Middletown, Conn.
BOLTON, CHANNING MOORE..........The Cosmos Club, Washington, D. C.
BROWN, ALBA FISK ....271 40th St., Pittsburg, Pa.
BUTLER, MATTHEW JOSEPH..........17 St. James Place, Chicago, Ill.
CRAIGHILL, WILLIAM PRICE.........Charlestown, Jefferson Co., W. Va.
DENNIS, WILLIAM FRANKLIN.........308 E. Clay St., Richmond, Va.
MCGRATH, WALLACE................1125 Tennessee St., Lawrence, Kan.
PEARL, JAMES WARREN..............Engr. and Contractor, Warsaw, Ind.
RIFFLE, ALBERT STANLEY...........Care of S. F. & S. J. V. R. R., 321 Market St., San Francisco, Cal.
TAYLOR, JAMES TOWNSEND...........Chf. Engr. Pecos Irrig. & Imp. Co., and the Pecos Valley Town Co., Eddy, New Mexico.

ASSOCIATE MEMBERS.

BRYAN, KENNERLY..................Howard Iron Works, Buffalo, N. Y.
CONNOR, EDWARD HANSON...........Athens, Pa.
MITCHELL, HORACE HULBURD........20 Ninth Ave., Newark, N. J.
MONTONY, LIBERTY GILBERT.........Care of Metropolitan Street R'y Co., 621 Broadway, New York City.
MOORE, CHARLES HARRY............Asst. Engr. Erie R. R. Co., 21 Cortlandt St., New York City.
WHEATLEY, ARTHUR CORNWALLIS.....Fabricia Luz Electrica, Colon, City of Mexico.

JUNIORS.

BLODGETT, JOHN...................East Side House, 76th St. and East River, New York City.
EVANS, PETER PLATTER.............The King Bridge Co., 73 Tremont St., Boston, Mass.
HARTWELL, HARRY.................119 East 77th St., New York City.
MOISSEIFF, LEON S.................66 Broadway, Room 143, New York City.

ADDITIONS TO

LIBRARY AND MUSEUM.

From American Institute of Architects, Providence, R. I.:
Proceedings of the Thirtieth Annual Convention, 1896.

From Board of Supervisors, San Francisco, Cal.:
San Francisco Municipal Reports for the fiscal year ending June 30th, 1896.

From Board of Trustees of the Sanitary District of Chicago:
Proceedings January 6th, 13th, 20th and 27th, 1897.

From California State Mining Bureau, Sacramento, Cal.:
Thirteenth Report (Third Biennial) of the State Mineralogist for the two years ending September 15th, 1896.

From E. L. Corthell, New York, N. Y.:
Remarks on a Bill to Provide for the Closing of the Pass-à-Loutre Crevasse and for the Improvement of the Southwest Pass at and near the Mouth of the Mississippi River.

From Charles Evan Fowler, Youngstown, Ohio:
General Specifications of Steel Roofs and Buildings.

From Fuel Economizer Company, New York, N. Y.:
Green's Economizer.

From Harvard University, Cambridge, Mass.:
Annual Reports of the President and Treasurer, 1895-96.

From H. A. Hazen, Washington, D. C.:
The Mechanism of a Tornado.

From E. A. Hermann, St. Louis, Mo.:
Steam Shovels and Steam Shovel Work.

From Hungarian Society of Engineers, Budapest, Hungary:
List of Members for 1897.

From Institute of Marine Engineers, Stratford, Eng.:
Seventh Annual Volume, 1895-96.

From Institution of Civil Engineers, London, Eng.:
List of Members, January 2, 1897.

From Metropolitan Job Print, New York, N. Y.:
United States Official Postal Guide, January, 1897.

From New England Cotton Manufacturers' Association, Boston, Mass.:
Transactions, No. 61.

From Edward P. North, New York, N. Y.:
Photographic View of New York, from Water Purveyor's Office, D. P. W., 150 Nassau Street, 17th Floor, looking South to West.

From Nova Scotia Institute of Science, Halifax, N. S.:
Proceedings and Transactions, Vol. IX. Session of 1895-96.

From Patent Office, London, Eng.:
Abridgments of Specifications for Patents for Inventions; Animal-Power Engines and Miscellaneous Motors; Lamps, Candlesticks, Gasaliers and Other Illuminating Apparatus; Road Vehicles; Ventilation; Packing and Bailing Goods; Hydraulic Engineering; Nails, Rivets, Bolts, Nuts and Screws, Ornamenting; Electricity, Regulating and Distributing; Buildings and Structures; Grinding or Abrading and Burnishing.

From Philosophical Society of Glasgow, Glasgow, Scotland:
Proceedings, Vol. XXVII, 1895-96.

From William T. Pierce, Boston, Mass.:
Report of the Board of Metropolitan Park Commissioners, Boston, Mass., January, 1897.

From Railroad Commissioners of Maine, Augusta, Me.:
Thirty-eighth Annual Report for the year ending June 30, 1896.

From Royal Institute of Engineers, Hague, Holland:
Verhandelingen, Vertalingen, etc., Eerste Aflevering, 1896-97.
Notulen der Vergaderingen, Vijfde Aflevering, 1895-96; Eerste Aflevering, 1896-97.

From O. E. Schultz, Pittsburg, Pa.:
Framed photograph of Bridge in Schenley Park, Pittsburg, Pa., over Panther Hollow.

From J. B. Snow, Boston, Mass.:
Standard Specifications for Metal Bridges carrying tracks of the Boston and Maine Railroad, 1896.

From State Agricultural College, Fort Collins, Colo.:
Eighteenth Annual Report, including Ninth Annual Report of the Agricultural Experiment Station, 1896.

From Wm. H. Tolman, Secy., New York, N. Y.:
Report on Public Baths and Public Comfort Stations.

From E. E. Russell Tratman, New York, N. Y.:
The Relations of Track to Traffic on American and Foreign Railways.

From John C. Trautwine, Jr., Philadelphia, Pa.:
Ninety-fourth Annual Report of the Bureau of Water, with Ninth Annual

Report of the Department of Public Works, Philadelphia, Pa., for the year ending December 31, 1895.
Message of the Mayor of Philadelphia, Pa., with Annual Reports of the Departments, 1895. 4 vols.

From U. S. Department of Agriculture:
Report of the Secretary of Agriculture, 1896.

From U. S. Department of the Interior:
Annual Report of the Commissioner of Patents for the year 1895.

From U. S. Treasury Department, Bureau of Statistics:
Statistical Abstract of the United States, 1896.

From U. S. War Department, Chief of Engineers:
Fifteen Reports on the Improvement of Certain Rivers and Harbors.
Nine Specifications for the Improvement of Certain Rivers and Harbors.

From University of the State of New York, Albany, N. Y.:
State Library Bulletin, Legislation No. 7, Legislation by States in 1896.

From University of Wisconsin, Madison, Wis.:
Bulletin No. 10, Topographical Surveys, their Methods and Value.

By Purchase:
The Engineering Index, Vol II, 1892-1895.

BOOK NOTICE.

A TEXT-BOOK ON PLANE SURVEYING.

By William G. Raymond, M. Am. Soc. C. E. Cloth, 6 x 9 ins., pp. 469. With cuts and plates. American Book Company. New York, Cincinnati, Chicago, 1896.

This work, as its title indicates, is intended as a text-book for teachers or for those beginning the study of surveying. The author has left to the teacher the work of amplification of the subject rather than giving himself full explanation of the topics treated. Those points, however, which a long experience in teaching has shown him present the greatest difficulty have had special treatment.

The first part of the work is a description of the principal instruments used in surveying, with directions for their care and adjustment and the elementary operations performed by them. Chapters are given to the measurement of level and horizontal lines, of altitudes, and of determination of direction and measurement of angles. A special chapter is given to stadia measurements, in which the method is explained and diagrams given for reducing the observations. The second part of the book is given to general surveying methods, and public and private, as well as city, surveys are treated. The United States public land surveys are described and exemplified in plots of theoretical townships, showing the divisions required by legal enactment by the Government. The laying out of curves is described in another chapter, and this is followed by chapters treating of topographical surveying, earthwork computations, hydrographic and mine surveying.

An appendix is added, giving a large number of problems and examples in the work of surveying, and articles on the judicial functions of surveyors, the ownership of surveys and what constitutes a survey, and the geographical positions of base lines and meridians in public surveys. A collection of tables useful to surveyors and several plates showing methods of topographical mapping close the volume.

1897. FEBRUARY. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS:

THE COMPRESSIBILITY OF SALT MARSH UNDER THE WEIGHT OF EARTH FILL.

By EUGENE R. SMITH, Jun. Am. Soc. C. E.

TO BE PRESENTED MARCH 17TH, 1897.

The importance of the dredging interests in and about the great cities of the sea coast cannot easily be overestimated; the very existence of the harbors and channels through which intercourse with the outside world is carried on, as well as the locations of piers and warehouses for the convenience of this intercourse, is often dependent upon the efficiency of the dredge. The methods formerly employed were comparatively expensive, and the work was confined to the improvement of the more necessary channels and the filling for the more important

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

docks, warehouses and railroad terminals where the large business transactions warranted large outlays of money.

The present reduced cost of dredging due to the introduction of hydraulic methods makes practicable many plans of real estate development, which up to the time of these improvements could not be considered because of the prohibitory cost. Among these projected plans is the reclamation of tracts of marsh or meadow land bordering the salt water creeks and bays in the vicinity of cities and large towns. The extent of such marsh land which might be made valuable for both business and residential purposes in the vicinity of New York may be appreciated when it is considered that within a radius of 15 miles of the City Hall the area of such land is three times as great as that of Manhattan Island.

The growth of the cities and the increasing demand for summer homes, together with the reductions in the cost of dredging, open an important and comparatively new field for both the engineer and contractor in the reclamation of these lands, not only about New York, but near every large center of population on the Atlantic seaboard. From the standpoint of the engineer one question of interest in an investigation or report on such a proposed work is the compressibility of the marsh under the weight of the requisite filling material.

During the fall of 1894 an opportunity was afforded for obtaining information on this question; the author was called upon to prepare a specification and solicit bids for the reclamation of 80 acres of such marsh land on the north shore of the Great South Bay, opposite Fire Island Light, at Islip, Suffolk County, N. Y. The underlying material is sand and gravel, with occasionally a little clay, the surface of which slopes gradually from the lower edge of the adjacent upland to the bay. This marsh, locally known as "meadow," consists of a growth of various salt grasses on the surface of the mud just above the level of ordinary high tide. This mud is the accumulation of decayed seaweed and other vegetable matter, and, owing to its composition and location, is soft and compressible. The surface of this meadow sod is, so far as the author's experience and observation goes, practically level and just above ordinary high tide, 0.4 ft. in this case. This sod growth forms a kind of leathery covering over the mud, distributing the pressure due to the weight of the filling material above upon the mud below, and preventing it from

breaking through and being replaced by the heavier sand. The pressure on the mud from the fill above tends to increase the consistency of the mud by squeezing out the water until a condition of equilibrium is reached. It is a matter of conjecture whether the water rises through the sand and adjacent meadow to the surface and is dried out by the air or oozes horizontally out to the bay and creek; probably it does both.

The average thickness of the meadow sod and mud is 4.3 ft., the maximum thickness being 9.5 ft.; the ordinary rise and fall of tide is 15 ins.

The specification called for a fill of earth to a height of 3 ft. above the original level of the meadow surface, the contractor to assume the responsibility for the compression of the meadow sod up to the date of completion of the total work. As the contract price was per acre of finished fill without regard to the compression of the meadow, the investigation as to the compression would have no bearing on this undertaking, but the opportunity for an examination of the matter was too favorable to be neglected.

The total area to be filled was divided into squares of 100 ft. At each corner a stake was driven through the meadow firmly into the underlying sand and gravel, and the top was sawed off at the 3-ft. grade level. A board about 1 ft. square, with a short stake nailed to one edge, was placed on the meadow surface at the side of each grade stake, the short stake being pushed into the meadow sod so that the board could remain where placed at the surface and not be washed out of position as the filling took place. The thickness of the meadow sod was ascertained by pushing down a half-inch iron rod to the sand, and the thickness of the filled material from the surface down to the board was similarly determined. By referring all elevations to the top of the grade stake, the amount of compression was readily ascertained. The whole area includes all kinds of meadow, from hard to soft, so that the result may fairly be considered as representative of meadow where the rise and fall of the tide does not differ materially from that stated.

The contract was awarded to Messrs. Charles Vivian & Company. They used one hydraulic dredge, equipped with an 18-in. centrifugal pump, which was run at a maximum speed of 250 revolutions per minute. The suction and discharge were also 18 ins. in diameter. The filling

material was almost entirely sand from the bay and from canals dug through the meadow; the sand was a very sharp quartz, which caused serious wear on the pump, which was finally obviated by the use of hardened steel linings. These protected the pump shell and could be readily replaced as they became worn. The weight of the filling material (sand) varies from 2 875 lbs. to 2 956 lbs. dry and from 3 037 lbs. to 3 118 lbs. wet per cubic yard, the wet sand being about 5½% heavier than the dry.

In the accompanying tables the percentages given are with reference to the thickness of the meadow, and where a percentage is noted, in order that its proper value may be apparent, the number of observations of which it is the average is noted. A subdivision as to thickness is also made into five classes as follows: 1.5 to 3.5 ft. inclusive; 3.6 to 4.5 ft. inclusive; 4.6 to 5.5 ft. inclusive; 5.6 to 6.5 ft. inclusive. and 6.6 ft. and upward, so that any peculiarity due to different thicknesses might be disclosed. It is also proper to state that the averages are carried out to tenths of 1% in order that any ratio or tendency shown by the results might be more easily noted and studied, rather than with any idea of determining the actual compression with mathematical exactness to a fraction of an inch.

TABLE No. 1.—Percentages of Compression for Various Periods and Depths of Meadow.

Duration of Time.	Percentage of Compression and Number of Stations observed, for Thickness of Meadow Sod as Shown Below.											
	1.5 to 3.5 ft. Av., 2.7 ft.		3.6 to 4.5 ft. Av., 4 ft.		4.6 to 5.5 ft. Av., 5 ft.		5.6 to 6.5 ft. Av., 5.9 ft.		Over 6.5 ft. Av., 7.9 ft.		For all thicknesses combined.	
	Per-cent.	No. sta.	Per-cent.	No. sta.	Per-cent.	No. sta.	Per-cent.	No. sta.	Per-cent	No. sta.	Per-cent.	No. sta.
1 mo....	7.7	49	10.6	47	11.7	37	10.0	20	10.9	19	10.0	172
2 mos...	10.1	49	14.2	47	14.8	37	12.8	20	14.8	19	13.1	172
3 mos...	11.8	48	15.0	43	16.4	36	12.8	17	16.5	19	14.3	163
4 mos...	12.3	47	16.0	43	17.1	36	13.8	17	17.5	19	15.1	162
5 mos...	12.5	47	16.4	43	17.6	36	14.4	17	18.2	19	15.5	162
6 mos...	12.9	45	16.9	39	18.1	34	14.0	11	18.6	19	15.9	148
7 mos...	13.5	43	17.4	36	19.4	28	15.7	9	19.4	19	16.7	135
8 mos...	13.1	39	17.7	27	20.2	25	17.4	7	20.1	15	16.9	113
9 mos...	12.6	36	17.9	22	19.7	17	17.7	7	20.7	14	16.6	96
10 mos...	10.9	32	17.0	19	20.0	12	18.3	6	21.6	13	16.2	82
11 mos...	11.1	25	17.8	13	20.8	10	24.0	2	22.0	13	16.7	63
12 mos...	11.1	21	20.5	4	22.3	6	26.0	1	27.6	6	16.9	38

TABLE No. 2.—Distribution of the Total Percentage of Compression Throughout the Successive Months, for All Thicknesses Combined.

No. of stations.	Total percentage of compr.	1st mo.	2d mo.	3d mo.	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.	11th mo.	12th mo.
12....	22.4	10.2	5.0	2.8	1.0	1.0	0.7	0.1	0.6	0.1	0.4	0.3	0.2
34....	16.5	7.9	3.3	2.1	0.7	0.2	0.6	0.7	0.0	0.2	0.4	0.3	0.1
38....	16.9	8.3	3.4	2.2	0.5	0.3	0.5	0.3	0.3	0.4	0.3	0.1	0.3
63....	16.7	8.3	4.0	1.4	0.6	0.3	0.4	0.4	0.3	0.3	0.3	0.4	.....
82....	16.2	8.0	3.6	1.5	0.9	0.2	0.7	0.3	0.3	0.3	0.4	.....	.....
96....	16.6	9.0	3.3	1.6	0.8	0.3	0.5	0.4	0.3	0.4	.....	.....	.....
113....	16.9	9.7	3.3	1.5	0.8	0.3	0.5	0.4	0.4	.....	.....	.....	.....
135....	16.7	9.7	3.2	1.3	0.8	0.4	0.7	0.6	.....	.....	.....	.....	.....
148....	15.9	9.6	3.2	1.3	0.8	0.3	0.7	.....	.....	.....	.....	.....	.....
162....	15.5	9.8	3.1	1.3	0.9	0.4	.....	.....	.....	.....	.....	.....	.....
162....	15.1	9.8	3.1	1.3	0.9	.....	.....	.....	.....	.....	.....	.....	.....
163....	14.3	9.8	3.1	1.4	.....	.....	.....	.....	.....	.....	.....	.....	.....
172....	13.1	10.0	3.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE No. 3.—Comparison of Average Compression with Compression for Thin, Medium and Thick, Meadow.

Duration of Time.	General Average. See Table No. 1.		Thin Meadow. 1.5 to 3.5 Ft. inclusive. Average Thickness = 2.7 Ft.			Medium Meadow. 3.6 to 6.5 Ft. inclusive. Average Thickness = 4.7 Ft.			Thick Meadow. 6.6 Ft. and Upward. Average Thickness = 7.9 Ft.		
	Number station.	Percentage.	Number station.	Percentage.	Variation from general average.	Number station.	Percentage.	Variation from general average.	Number station.	Percentage.	Variation from general average.
1 mo....	172	10.0	49	7.7	− 2.3	104	10.9	+ 0.9	19	10.9	+ 0.9
2 mos...	172	13.1	49	10.1	− 3.0	104	14.1	+ 1.0	19	14.8	+ 1.7
3 mos...	163	14.3	48	11.8	− 2.5	96	15.1	+ 0.8	19	16.5	+ 2.2
4 mos...	162	15.1	47	12.3	− 2.8	96	16.0	+ 0.9	19	17.5	+ 2.4
5 mos...	162	15.5	47	12.5	− 3.0	96	16.5	+ 1.0	19	18.2	+ 2.7
6 mos...	148	15.9	45	12.9	− 3.0	84	17.0	+ 1.1	19	18.6	+ 2.7
7 mos...	135	16.7	43	13.5	− 3.2	73	17.9	+ 1.2	19	19.4	+ 2.7
8 mos...	113	16.9	39	13.1	− 3.8	59	18.7	+ 1.8	15	20.1	+ 3.2
9 mos...	96	16.6	36	12.6	− 4.0	46	18.5	+ 1.9	14	20.7	+ 4.1
10 mos...	82	16.2	32	10.9	− 5.3	37	18.4	+ 2.2	13	21.6	+ 5.4
11 mos...	63	16.7	25	11.1	− 5.6	25	19.5	+ 2.8	13	22.0	+ 5.3

Note.—In taking the average percentage of compression for all thicknesses, it is assumed that it is independent of the thickness of the meadow. This is not strictly correct, the percentage of compression for thin meadow being less than, and for thick meadow more than, for the general average as shown above for all thicknesses.

Some experience of the author in Jamaica Bay during 1896 on the same kind of work shows the percentage of compression to be materially less where the rise and fall of the tide is greater (4 to 6 ft. in Jamaica Bay), other things being equal. The information there obtained was not sufficiently extensive to authoritatively warrant any more definite statement than this; the same relative level, practically, is maintained between the surface of the meadow and ordinary high tide, and it is suggested that the opportunity for drying out of the upper portion of the meadow sod during a part of each tide tends to harden the sod, and make it less compressible than where it is saturated all the time.

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PAPERS.

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NOTES ON PORTLAND CEMENT CONCRETE.

By ANDREAS LUNDTEIGEN, Esq.

TO BE PRESENTED APRIL 7TH, 1897.

A number of years ago the Society of German Portland Cement Manufacturers published an article claiming that good Portland cement could not be improved by admixtures. It seems likely that the purpose of that article must have been to counteract any endeavor by dishonest men to add poor admixtures, and thus lower the reputation of German Portland cement, which then had begun to invade the markets of the world. It is also possible that experiments with many cements made before that time would not show the advantage of fine silicious admixtures, as well as the present high-limed and high-testing cements. Besides it may also be that both good and valueless admixtures were treated under one head, and therefore condemned.

It is worth mentioning that although the use of hydraulic mortars is very old, and a thorough knowledge of the nature of setting and hardening is very important, is was not until recently that much

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

had been done in this line. Whenever failures in concrete works were reported, they were attributed either to poor workmanship in the construction or to bad cement, while in reality neither was the cause. A cement was regarded bad when it contained, through careless manufacture, too much free lime, magnesia or sulphuric acid. The harmful effect of free lime has always been well enough known, but there is at the present day, with improved machinery and methods of manufacture, no excuse for such free lime, and it is not often met with in practice. An amount of magnesia above 1½% was long regarded dangerous, and even to-day there are many specifications calling for a cement with less than 2% magnesia. The German manufacturers, to whom this magnesia question has been of most importance, have discussed it in their meetings and in their papers for a long time. The result is that to-day 3% of magnesia in Portland cement is thought harmless, and many claim that even 5% ought to be allowed. It seems to the author that this difference of opinion has resulted not so much from the different amounts of magnesia in the cement as from the excess, more or less, of basic constituents, such as lime, magnesia and alkalies. Sulphuric acid has been considered harmless in Portland cement only to the amount of 1 to 1½ per cent. A closer investigation of the effect of sulphates in concrete was first made by Messrs. Erdmenger, Candlot and Michaëlis.* The results are, in short, that the amounts of alumina play an important part, and that it is of material difference whether the sulphates are added before or after burning. If they are intimately mixed with the raw materials a considerable quantity may not only be allowed in the cement, but is beneficial.

The author does not believe that consumers run much risk from any of the previously mentioned causes of faulty cements, because there are very few cements that contain an excess of free lime, magnesia or sulphuric acid, and if such should be the case, ordinary tests in cold water would in a few days show the bad effects of sulphates, a simple analysis would give the amount of magnesia, and a 28 days' cold-water test or a few days in hot water would show the free lime. The principal danger in concrete construction has nothing to do with the abovementioned causes, but comes from using high-grade, well-manufactured cements, in which an extreme fineness in the grinding of raw materials

* See *Thonindustrie Zeitung*, 1891, p. 925; and Candlot's work, entitled "Cements et Chaux Hydrauliques," 1891, pp. 243, 263.

and of the finished products together with a uniform, hard burning, enables the manufacturers to increase the amount of the basic elements to a maximum without getting an appreciable amount of free lime. Such a cement will, in a short time, obtain a very high degree of strength and give excellent satisfaction wherever used in air or away from the continual action of water. For such work it may take more sand and make a more durable concrete than the old-fashioned low-limed and coarsely ground cements. It is different, however, where the concrete is to be used under water, be it fresh or salt. Then high-limed, high-grade cements will not only prove inferior but dangerous, especially if the water is rich in sulphates,‡ as shown in Table No. 1.

TABLE No. 1.—Tensile Strength.

Cement Sample.	Pat Test.		Fineness. Residue on—		Neat Cement.					1 Cement to 4 Sand.				
	Cold.	Hot.	50 mesh.	100 mesh.	7 days.	28 days.	6 months.	1 year.	2 years.	7 days.	28 days.	6 months.	1 year.	2 years.
a	Good.	Good	1.0	6.0	528	731	752	797	854	133	160	249	263	185*
b	"	"	1.0	6.0	563	785	806	803	956	108	173	192	143*	000*
c	"	"	4.0	14.5	422	547	664	730	851†	80	114	131	128	103*
d	"	"	6.5	19.5	528	692	730	752	813	90	119	172	151*	19*
e	"	"	2.5	18.0	396	572	740	795	774†	71	117	151	154	107*
f	"	Loose from glass.	4.0	19.5	481	579	802	853	970	62	113	219	233	184
g	"	Good.	6.0	23.0	563	696	821	884	955	59	108	218	256	266
h	"	"	5.0	21.0	364	502	804	912	923	40	96	197	216	194
i	Surface scaled off.	"	4.0	18.0	349	541	876	831	835	32	105	200	226	238

* These briquettes were cracked very much.
† " " " " at the corners.

Each of the tests in this table, with the exception of those for two years, is an average of five breakings. The two-year tests in this table and all the tests given in the remaining tables are each an average of three breakings. In order to make comparison easier, decimals have been omitted. The same sand was used for all the tests; it was passed through a 16-mesh and retained on a 20-mesh sieve. All briquettes were made by hand, and such amounts of water used as would give the best results with each individual cement.

‡ See also *Thonind. Zeitg.*, 1896, No. 25; article by Dr. Stutzer.

The water used, both for gauging and immersion, was well water, containing in one liter:

$CaSO_4$,	1.0214	grams.
$MgSO_4$,	0.2238	"
NaCl,	0.1515	"

Samples *a*, *b* and *e* were German Portland cement, *c* was Belgian, and *d* English; *f*, *g*, *h* and *i* were samples of an American Portland cement. Samples *e* and *i* had been kept in the laboratory about 18 months, and were somewhat lumpy; the others seemed comparatively fresh and in the best condition.

It becomes apparent from an inspection of the sand tests in Table No. 1, that those briquettes which broke the highest in a short time fared worst in the long run, and analysis shows that those cements contain more basic elements, lime and magnesia, in proportion to acid elements, silica, alumina and oxide of iron, than the other samples.

It has long been evident to the author that under the hardening of cement mortar a part of the lime is continually set free or separated from its molecular combination with silica, alumina or iron; in other words, these last substances are able to combine with more lime and magnesia in a dehydrated state in the kilns than in a hydrated state in the mortar. Dr. Michaëlis* finds that 33% of the lime in the average Portland cement is set free and will seek other material to combine with. If reached by the air it will take up carbonic acid and form a carbonate, which does not injure the concrete; in pure water it will be washed away in the water, and the concrete will be left more porous and weaker; in sea-water, or water containing mineral salts, these salts will combine with the calcium hydrate and form voluminous double salts, which will swell and destroy the concrete. Mr. Gerhart Herfeldt discusses this same subject, and shows, like Dr. Michaëlis, how Portland cement can be improved by admixture of trass, but his tests only cover 28 days, which, as said before, is not enough to show the full value of the admixture.

The author has often noticed that unwashed sand would give better tests than well washed and cleaned sand, and he can account for it only in this way, that the fine-clay substance in the sand is able to

* In an excellent article entitled "Das Verhalten des hydraulischen Bindemittel Zum Meerwasser," published in *Verhandlungen des Vereins zur Beförderungen des Gewerbfleisses*, 1896, Nos. 6 and 7.

combine with the liberated lime-hydrate in the cement. It was this circumstance which first gave him the idea of improving concrete by adding a certain quantity of fine silicious materials ; and experiments made subsequently more than satisfies him of the correctness of his first supposition. Out of many tests, more or less systematically carried on, the results of a few, which agree in everything with the others, are given in Tables Nos. 2 and 3.

TABLE No. 2.

	Neat cement.	1 part cement. 3 parts sand. water 12%.	1 part cement. 1 part sil. 3 parts sand. water 12%.
7 days	419	77	33
28 "	554	136	100
6 months	847	264	341
11 "	950	298	470
2 years	......	......	582

TABLE No. 3.

	Neat cement.	1 cement. 2.5 sand. water 12%	1 cement. 1 sil. 5 sand. water 12.8%
7 days	507	89	40
28 "	685	163	125
4 months	911	252	314
11 "	917	254	374

Table No. 4 shows the compression tests in pounds per square inch.

TABLE No. 4.—Compressive Strength, Pounds Per Square Inch.

	German Portland Cement.		American Portland Cement.	
	1 cement. 4 sand.	1 cement. 1 sil. 8 sand.	1 cement. 4 sand.	1 cement. 1 sil. 8 sand.
7 days	445	218	282	167
28 "	776	441	603	320
80 "	1 047	700	945	558
6 months	306	901	1 094	805
12 "	......	1 518	1 403	1 409
1 day in air; 36 days " cold water; 10 " " boiler with pressure between 20 and 90 lbs.	836	more than 2 030*	1 846	1 804

* The testing machine could break only as high as 2 030 lbs.

Table No. 5 shows the results of varying proportions of cement and silicious material. Cement *A* is American, and cement *G* is German, the same as *a* in Table No. 1.

TABLE No. 5.—RESULTS OF VARYING THE PROPORTIONS OF THE INGREDIENTS.

	NEAT CEMENT.		2 CEMENT. 1 SIL.	1 CEMENT. 1 SIL.		1 CEMENT. 2 SIL.	2 CEMENT. 6 SAND.		2 CEMENT. 1 SIL. 6 SAND.	1 CEMENT. 1 SIL. 6 SAND.		1 CEMENT. 2 SIL. 6 SAND.
	A.	*G.*	*A.*	*A.*	*G.*	*A.*	$A._1$	G_1	*A.*	$A._2$	$G._2$	*A.*
7 days	464	566	233	95	147	42	129	185	55	27	52	Too poor to break.
28 "	601	800	284	154	243	84	183	223	115	92	92	76
80 "	...	....	......	....	....	......	248	215	181	151	131	141
6 months	....	....	513	373	504	262	293	294	256	213	218	175
12 "	882	891	683	546	613	474	366	287	414	422	415	404
							*436	*287	....	*292	*305	

* 1 day in air; 10 days in cold water; 10 days in boiler with a pressure between 20 and 90 lbs. per inch.

Fig. 1 shows A_1, G_1, A_2 and G_2 graphically.

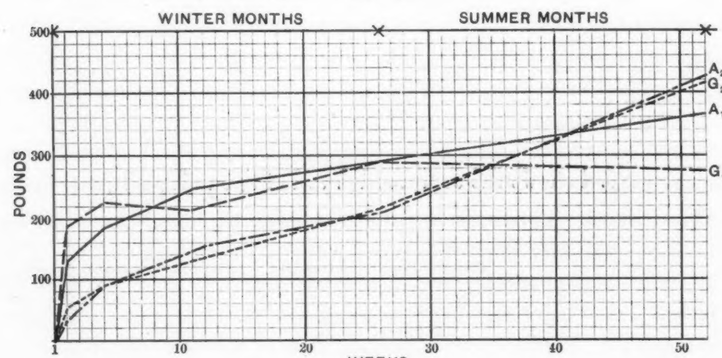

FIG. 1.

Such are the author's results invariably with silicious admixtures with Portland cements. What in the above experiments is called sil is a volcanic ash found in great quantities in Nebraska, Colorado, and other places. Its chemical composition is very similar to that of santorin earth from Greece and trass from Germany. The analysis of the sample used for most of his experiments he found to be:

Silica	71.78
Titanic acid	0.80
Alumina	12.71
Oxide of iron	2.29
Magnesia	0.35
Lime	1.01
Water of composition	4.52
Alkalies (by difference)	6.54
	100.00

The composition varies, however, in the different localities and possibly at different depths in each deposit. Dr. Erdmenger found in a sample sent him from another locality:

Silica	81.28
Alumina, Oxide of iron	13.80
Magnesia	Trace
Lime	0.09
Loss by ignition	4.57

Insoluble in HCl. .... 94.66 per cent.

By long and repeated boiling in caustic soda solution only 3 per cent. remained undissolved.

Such ashes as contain the most chemically bound water are considered best for cement admixtures, although the author believes that in a long run there will be much difference.

As a rule such ashes are found in layers from 5 to 10 ft. deep, but the author is told that in Colorado much thicker layers are found. In the banks it is somewhat moist and can be shoveled out easily; when dry, part of it will be lumpy, especially the more impure varieties. Squeezed out, it will have less than 1% residue on a 100-mesh sieve. The color is either gray or white, the gray being the cleanest, but coarsest. It is believed to originate from volcanic eruption; being carried by the wind, it would settle in small quiet lakes, which would fill up, solidify and afterwards be covered with dirt.

Such volcanic ashes and similar material, like trass and pozzolana, have been used with hydraulic limes for water mortars far back in history; thus Smeaton used them in the Eddystone Lighthouse in 1856–59. The author does not know, however, that they have been used to any extent with Portland cement.

Where such ashes, trass or pozzolana cannot be had at a reasonable price, other materials may be used. Waste products from alum factories and certain silicious slags are said to give very good results. Certain kinds of clay and sand when ground extremely fine will also give good satisfaction. It is the author's experience that sand and cement ground together (sand cement) will give higher tests in a short

time than when the cement and sand are ground separately and mixed afterwards, but in a long-time test it does not seem to make any difference. How powerful such fine silicious material is in combining with free lime can best be seen by adding increasing amounts of unslacked or partially slacked lime tc Portland cement, and then making briquettes with and without the silicious admixture. Table No. 6 contains results of such tests, and Fig. 2 is a diagram of the same data.

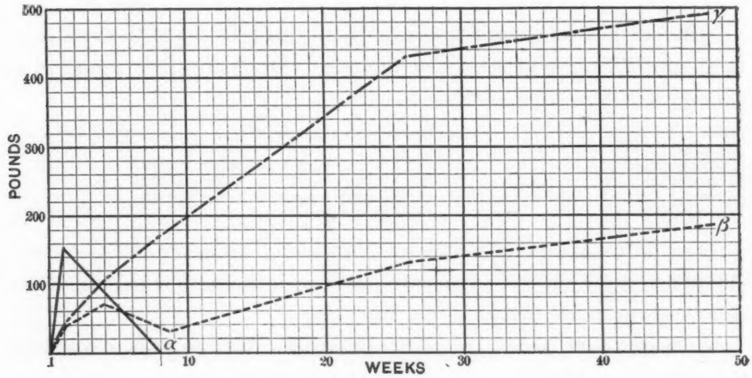

FIG. 2.

TABLE No. 6.

	1 cement. 0.5 partially slacked lime. 4 sand. α	1 cement. 0.5 partially slacked lime. 8 sand. 1 sil. β	1 cement. 2.0 partially slacked lime. 6 sand. 1 sil. γ
7 days....	154	36	41
28 "	88	64	107
60 "	Fallen to pieces.	37	174
180 "	....	132	435
330 "	....	168	492

It is here specially interesting to study the middle column of the tests, β. It will be seen that while the destructive force of the free lime makes itself more and more prominent in the first 60 days, in which time the briquettes in column α are entirely destroyed, the briquettes column in β, while weakened somewhat, are able to regain strength and act like sound concrete, showing that the expansive force of the lime has been overcome. Column γ shows a steady and uniform increase, which indicates the perfect soundness of the concrete from the start.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will hereafter be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

ALEXANDER SAMUEL DIVEN, F. Am. Soc. C. E.*

DIED JUNE 11TH, 1896.

Descended from Scotch-Irish ancestry, General Alexander Samuel Diven was born February 10th, 1809, in the then town of Catherine, Tioga County, N. Y., now the town of Dix, Schuyler County. He was the son of Captain John Diven, a soldier of the Revolution.

General Diven's early education was acquired in the schools of his native town and in the academies at Penn Yan and Ovid. In 1830 he went to Elmira and entered the office of the late Judge Hiram Gray as a student at law. In this office and that of Fletcher Haight at Rochester he completed his legal studies, maintaining himself in the mean time in part by teaching school in Elmira, and in part at Owego as Deputy County Clerk of Tioga County, which then comprised Chemung County and the present city of Elmira. Admitted to the bar he went to Angelica, Allegany County, in 1833, and opened an office in partnership with George Miles, who a few years later removed to Michigan. General Diven continued his practice alone at Angelica until 1845, when he removed to Elmira. His practice in Angelica was extensive and covered a large portion of western New York. Soon after removing to Elmira he became a member of the firm of Diven, Hathaway and Woods, which, during its existence of fifteen years, was a leading law firm in southern New York. This partnership continued until July, 1861, when it was dissolved to enable its senior member to form a new partnership with his son, George M. Diven. This latter partnership continued only a few years and did not receive much attention from its senior member, owing to the demands upon him of his political, military and business associations. A free soil democrat, General Diven was one of the organizers of the Republican party in the State of New York, and was ever prominent in its councils. He served one term, 1858–59, in the State Senate, and

* Memoir prepared by G. M. Diven, Esq.

in 1860 was elected a representative to the Thirty-seventh Congress, taking a leading part in its deliberations during that critical period in the nation's history.

In the summer of 1862, after the disastrous Peninsular campaign, when the call was issued for 300 000 men, at the personal solicitation of President Lincoln and Secretary Seward, General Diven and General R. B. Van Valkenburgh, representative from an adjoining district, leaving their seats in Congress, went to their homes to aid in raising a regiment in response to the call. This regiment, the 107th New York, was one of the first, if not the first, to respond to the call. It went out with General Van Valkenburgh as its Colonel and General Diven as Lieutenant-Colonel, and reached the front in time to take part in the battle of Antietam. Failing health compelled General Van Valkenburgh to resign his command, and General Diven succeeded to the colonelcy, continuing in command until after the battle of Chancellorsville, in which the regiment took part. Soon after this battle he was commissioned by President Lincoln as Brigadier General, by brevet, and appointed Assistant Provost Marshal General and assigned to the western district of New York, with headquarters at Elmira. This position he continued to hold until the close of the war.

While residing at Angelica, General Diven became interested in the construction of the New York and Erie Railroad and took an active part in extricating the company from its early difficulties and especially in aiding it to procure needed legislation, particularly that which released the company from the loan of $3 000 000 by the State. For several years he was Director, had charge as Commissioner for procuring right of way over a large portion of the line, and with his firm had charge of the legal business of the western end of the line. His connection with this road and its construction brought him into close relations with men eminent in their profession, who, as civil engineers, had charge of the work, among them Major T. S. Brown, William J. McAlpine, James P. Kirkwood and Julius W. Adams.

While engaged in the construction of the New York and Erie Railroad he became interested in the Chemung Railroad, extending from the New York and Erie Railroad, near Elmira, to the then village of Jefferson, now Watkins, at the head of Seneca Lake. He was a director in the company which built this road, which was opened in December, 1849, soon after the Erie Road was opened to Elmira and was operated in connection with the latter road as a continuous line from New York to Jefferson for a couple of years and until the completion of the line to Dunkirk. Soon after the completion of the Chemung Railroad General Diven became interested in the construction of a line from its northern terminus to Canandaigua. The company which constructed the latter road was originally chartered as the Canandaigua and Corning Railroad Company for the purpose of constructing a railroad from

Canandaigua to Corning. After the construction of the Chemung Railroad the title of the Canandaigua and Corning Company was by legislative enactment changed to the Canandaigua and Elmira Railroad Company and its route changed to connect with the Chemung Railroad, thus making a continuous line of railroad from Elmira to Canandaigua. The contract for its construction was made with a company of which General Diven was a member. After the completion of this road a still further extension was made by the construction of the Canandaigua and Niagara Falls Railroad, which was also constructed by the same firm of contractors. These three railroads were constructed with a 6-ft. gauge to correspond with that of the New York and Erie Railroad, and formed a continuous broad-gauge line from Elmira to Niagara Falls. The last built road becoming involved, it was sold on foreclosure, purchased in the interests of the New York Central Railroad Company, its gauge narrowed, and has since been operated by that company. The line from Elmira to Canandaigua is now under the control of the Northern Central Railway Company and is operated by it as a part of the Pennsylvania system in connection with the Elmira and Williamsport Railroad. Soon after the completion of the road to Canandaigua General Diven became interested in the construction of the Williamsport and Elmira Railroad. The Williamsport and Elmira Railroad Company was originally chartered by the legislature of the State of Pennsylvania in 1832, this being one of the earliest railroad charters in the United States. At an early day a line was constructed from Williamsport to Ralston and for a time operated with horses, but was soon abandoned and not used until about 1852, when General Diven took hold of the project, interested certain Philadelphia parties to raise the necessary capital, and, taking the contract for its construction, completed the road in the summer of 1854. While this road was under construction he was also interested in the construction of the Catawissa Railroad, extending from Milton to Tamaqua in the State of Pennsylvania, which, when finished, in connection with the Williamsport and Elmira and other roads formed a continuous line of railroad from Elmira to Philadelphia.

Shortly after the completion of these railroads he became interested in the construction of the main line of the Missouri Pacific Railroad, and was one of the firm of James P. Kirkwood & Company, which had a contract for constructing a large portion of the line. Afterwards, in connection with Lewis J. Stancliff, who had been a civil engineer in the construction of the Erie Railroad, and others, he formed a firm of contractors known as Diven, Stancliff & Co., which took the contract for constructing what was then known as the Southwest Branch of the Missouri Pacific Railroad, a line projected from Franklin on the main line of the Missouri Pacific to Neosho, in the southwestern portion of the state. This line was completed to Rolla, and the firm was engaged

on heavy work beyond, when the breaking out of the Rebellion stopped operations.

Upon the reorganization, after the foreclosure sale, of the New York and Erie Railroad Company into the Erie Railway Company in 1862 under the presidency of Nathaniel Marsh, General Diven was elected a Director, and his law firm, then consisting of himself and son, had charge of the legal business of the company west of Susquehanna. Upon the death of Mr. Marsh, soon after the close of the Civil War, General Diven was elected Vice-President of the company, a position he continued to hold, residing meantime in New York City until 1871, when he resumed his residence in Elmira. He again took the vice-presidency for a few months in 1872, when General Dix was called to the presidency. During this period, in connection with one of his sons, he was interested in a contract for the construction of the Jefferson Railroad, extending from near Susquehanna to Carbondale, Pa., which is operated as a branch of the Erie Railroad. With another son he afterwards constructed what is known as the Nineveh branch of the Albany and Susquehanna Railroad, extending from Nineveh to a connection with the Jefferson Railroad, constructed under the auspices of and operated by the Delaware and Hudson Canal Company. Still later he was engaged with the same son in the construction of a portion of the New York and Canada Railroad along the west shore of Lake Champlain.

With the completion of this work he closed active operations in business affairs. The rest of his life was spent at his old home in Elmira, except for the last twenty years he passed a few months each year at his winter place on the St. John's River, near the city of Jacksonville, Fla. While engaged in no regular active business, he kept himself in touch with the progress of events, took great interest in political affairs, and devoted much of his time and means to benevolent and educational institutions and enterprises. During nearly all his life he was an earnest and active member of the Presbyterian Church.

General Diven was married in 1834 to Amanda M. Beers, who died in 1875. Eight children, four sons and four daughters, were the issue of this marriage, of whom two sons and three daughters survive him. One of the surviving sons, John M. Diven, superintendent of the Elmira Water-Works Company, is an Associate of this Society. A second marriage took place in 1876 to Maria Joy, who still survives.

While the compiler of this sketch feels some delicacy about commenting on the character of the deceased, he may be pardoned for closing with the tribute of another, showing the esteem in which General Diven was held by those who knew him best. For many years he was a member of a select social and literary club which held monthly meetings, and at the first meeting of the club after his

death a member prefaced the essay he was to read with the following words:

"I should do less than justice to the emotion of the hour did I fail to voice our sense of loneliness at loss of him but yesterday the Nestor of our circle, so ripe in years, so strong in heart and mind, who since our last meeting has solved the magnificent mystery of death. To his ready soul doors have now swung open, upon whose threshold we have knocked in vain these many years. We shall not forget him. The sparkle of his wit, the dignity of his thought, his kindly sentiment to us each and all, as well, shall linger in our memory till the last of this little circle shall have ceased from earthly effort and followed in his departing footsteps."

General Diven was elected a Fellow of the American Society of Civil Engineers on June 16th, 1870.

FREDERICK JANVRIN CARREL, M. Am. Soc. C. E.*

DIED MAY 2D, 1894.

Frederick Janvrin Carrel was a native of St. Aubin, Jersey, England, where he was born on October 16th, 1852. After receiving an education at Cardiff and Malvern, he sailed from England for South Australia. Early in 1870 he obtained employment as Draftsman and Assistant in the office of the Engineer-in-Chief of the colony, and was engaged upon plans and parliamentary estimates for the Georgetown and Kapunda, and Narracourt and Lacepede Bay and other railways, and for harbor and bridge works.

In 1876 he resigned and came to this country. His first work was on the surveys for the West Side Irrigation and Navigation Canal, in California, and, after the completion of the field work, was employed in the office on plans and estimates of this canal. Later, he was engaged on the plans and estimates of the Feather River Water Company, which proposed to construct a system of water-works supplying San Francisco. Then he opened an office in San Francisco as Consulting Engineer, and made maps, sewer plans and mine and river surveys for some time.

In March, 1881, he was employed by the United States Government on the Cascades Canal, in Oregon, and was promoted to the position of First Assistant Engineer, remaining in this service until May, 1886. He then moved to Portland, Ore., where he established the Portland Smelting Works, and became interested in the purchase and sale of mining properties and ore. This business occupied most of his attention until his death, which occurred at Spokane, Wash., on May 2d, 1894. In 1890, he was associated with Mr. Oskar Huber in the construction of the water-works at Cheney, Wash.

He was elected a Member of the American Society of Civil Engineers on March 5th, 1884.

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*Memoir prepared from papers on file at the House of the Society.

Vol. XXIII. MARCH, 1897. No. 3.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publication.

CONTENTS.

SOCIETY AFFAIRS.

PAPERS.

The price of publications is as follows: Proceedings, $6 per annum; Transactions, $10 per annum. Postage will be added when they are sent to foreign countries.

American Society of Civil Engineers.

OFFICERS FOR 1897.

President, BENJAMIN MORGAN HARROD.

Vice-Presidents.

Term expires January, 1898:
WILLIAM R. HUTTON,
P. ALEXANDER PETERSON.

Term expires January, 1899:
GEORGE H. MENDELL,
JOHN F. WALLACE.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOHN THOMSON.

Directors.

Term expires January, 1898:
AUGUSTUS MORDECAI,
CHARLES SOOYSMITH,
GEORGE H. BENZENBERG,
GEORGE H. BROWNE,
ROBERT CARTWRIGHT,
FAYETTE S. CURTIS.

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HENRY S. HAINES,
LORENZO M. JOHNSON.

Assistant Secretary, JOHN M. GOODELL.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

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CHARLES WARREN HUNT,
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HENRY G. MORSE.

Special Committees.

ON UNIFORM STANDARD TIME:—Sandford Fleming, Charles Paine, Theodore N. Ely, J. M. Toucey, T. Egleston.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf, Thomas Rodd, A. E. Hunt.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—127 EAST TWENTY-THIRD STREET, NEW YORK.

Vol. XXIII. MARCH, 1897. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

March 3d, 1897.—The meeting was called to order at 20.30 o'clock, Vice-President William Rich Hutton in the chair; John M. Goodell acting as Secretary, and present, also, 70 members and 13 visitors.

Minutes of the meetings of February 3d and 17th, 1897, were approved as printed in *Proceedings* for February, 1897.

A paper entitled "Wind Pressures in the St. Louis Tornado" was presented by Julius Baier, Assoc. M. Am. Soc. C. E., and discussed by Messrs J. M. Knap, George S. Morison and Julius Baier. Written communications on the subject from Messrs. J. B. Johnson, Francis E. Nipher, H. A. Hazen and A. A. Stuart were presented by Mr. Goodell.

Ballots were canvassed and the following candidates declared elected :

As Members.

Charles Frederick Wilson Felt, Galveston, Tex.
Ephraim Harrington, Boston, Mass.
Stephen Thurston Hayt, Jr., Corning, N. Y.
Gunardo Aufin Lange, Buenos Ayres, Republic of Argentina.
Jacob Lott Ludlow, Winston, N. C.
Frank Otis Melcher, Fitchburg, Mass.
Ralph Modjeski, Chicago, Ill.
John Van Wicheren Reynders, Steelton, Pa.
Thomas Edward Snook, New York City.
Eugene Washington Stern, St. Louis, Mo.

As Associate Members.

Carleton Greene, Buffalo, N. Y.
Hardy Smith Ferguson, Berlin, N. H.
Benjamin Brentnall Lathbury, Philadelphia, Pa.
Hew Miller, New York City.
Robert Engler Neumeyer, Bethlehem, Pa.
John Gerard Theban, New York City.
Augustus Thompson Throop, Niagara Falls, N. Y.
John Shaw Walker, Sydney, New South Wales.

Announcement was made of the election by the Board of Direction on March 2d, 1897, of the following candidates:

As Juniors.

Creighton Hamilton Hollingsworth, Hartford, Conn.
George Ezra Ellis, Yonkers, N. Y.
Robert Henry Ford, St. Albans, Vt.
William Mackintosh, New York City.

Adjourned.

March 17th, 1897.—The meeting was called to order at 20.15 o'clock, President B. M. Harrod in the chair; Charles Warren Hunt, Secretary, and present, also, 64 members and 10 guests.

A paper by Eugene R. Smith, Jun. Am. Soc. C. E., entitled "The Compressibility of Salt Marsh Under the Weight of Earth Fill," was presented by the Secretary, who read correspondence on the subject from J. H. Clark, Assoc. M. Am. Soc. C. E. The paper was discussed by T. H. McCann, M. Am. Soc. C. E.

The Secretary announced that, under the Constitution, "a majority of a total vote of not less than one-third of the corporate membership of the Society" is necessary for the adoption of the proposition for the appointment by the Board of Direction of a special committee to report on the proper manipulation of tests of cement. One-third of the corporate membership have not sent in ballots, about thirty more votes being needed in order to arrive at a decision in the matter. Ballots may be obtained on application to the Secretary.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

March 2d, 1897.—Nine members present.

It was voted that in the future the letters of enquiry sent to the membership, asking their opinion as to the time and place of an Annual Convention, be sent out so as to be canvassed at the preceding Annual Convention.

Applications were considered and other routine business transacted.

Four candidates were elected as Juniors.

Adjourned.

ANNOUNCEMENTS.

MEETINGS.

Wednesday, April 7th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Andreas Lundteigen, Esq., entitled, "Notes on Portland Cement Concrete," will be presented. It was printed in *Proceedings* for February, 1897.

Wednesday, April 21st, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Wynkoop Kiersted, M. Am. Soc. C. E., entitled "Valuation of Water-Works Property," will be presented. It is printed in this number of *Proceedings*.

DISCUSSIONS.

Discussion on the paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled, "A Study in the Designing and Construction of Elevated Railroads, with Special Reference to the Northwestern Elevated Railroad and the Union Loop Elevated Railroad of Chicago, Ill.," which was presented at the meeting of February 17th, 1897, will be closed April 1st, 1897.

Discussion on the paper by Julius Baier, Assoc. M. Am. Soc. C. E., entitled, "Wind Pressures in the St. Louis Tornado," which was presented at the meeting of March 3d, 1897, will be closed April 15th, 1897.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Name	Address		Date of Membership.
FELT, CHARLES FREDERICK WILSON	2428 Strand, Galveston, Tex.		Mar. 3, 1897
HARRINGTON, EPHRAIM	19 Exchange Place, Boston, Mass		Mar. 3, 1897
HAYT, Jr., STEPHEN THURSTON	Eng. Fall Brook Ry. Co., Corning, N. Y.		Mar. 3, 1897
MELCHER, FRANK OTIS	Care of Webb Granite and Construction Co., 44 Front St., Worcester, Mass		Mar. 3, 1897
MODJESKI, RALPH	C h f. Eng., Rock Island Bridge, 1364 Monadnock Block, Chicago, Ill.	J. Assoc.M. M.	Dec. 3, 1886 July 1, 1895 Mar. 3, 1897
REYNDERS, JOHN VAN WICHEREN	Eng. in charge Bridge and Construction Dept., Penn. Steel Co., P. O. Box 87, Steelton, Pa.	Assoc.M. M.	June 1, 1892 Mar. 3, 1897
SNOOK, THOMAS EDWARD	261 Broadway, New York City		Mar. 3, 1897
STERN, EUGENE WASHINGTON	Eng. Koken Iron Works, St. Louis, Mo.		Mar. 3, 1897

ASSOCIATE MEMBERS.

Name	Address		Date of Membership.
AVERILL, FRANK LLOYD	1479 Columbia Road, Washington, D. C.		Jan. 6, 1897
CLARK, EDWIN	(Eng. in charge, Belmont Iron Works), 1612 North 10th St., Philadelphia, Pa		Jan. 6, 1897
LATHBURY, BENJAMIN BRENTNALL	1619 Filbert St., Philadelphia, Pa.		Mar. 3, 1897
LAWTON, FREDERICK BEECHER	128 West 42d St., New York City	J. Assoc. M.	Nov. 5, 1891 Nov. 4, 1896

		Date of Membership.
MILLER, HEW	14 Irving Place, New York City	Mar. 3, 1897
MOODY, BURDETT	Asst. to Chf. Eng., Homestake Mining Co., Lead, Lawrence Co., South Dakota	Feb. 3, 1897
SCOTT, WILLIAM ULYSSES	Asst. Eng., La. Div. Ill. Cent. R. R., 1240 Baronne St., New Orleans, La	Feb. 3, 1897
THEBAN, JOHN GERARD	149 East 116th St., New York City	Mar. 3, 1897

JUNIORS.

GREGORY, CHARLES EMERSON	28 West 61st St., New York City	Oct. 6, 1896
HOLLINGSWORTH, CREIGHTON HAMILTON	Room 402, Y. M. C. A. Bldg., Hartford, Conn.	Mar. 2, 1897

CHANGES AND CORRECTIONS.

MEMBERS.

BOLLER, ALFRED PANCOAST.........27 Pine St., New York City.
BRODHEAD, CALVIN EASTON...........Euclid, Butler Co., Pa.
CORTHELL, ELMER LAWRENCE..........27 Pine St., New York City.
DUNHAM, HERBERT FRANKLIN.........Aurora, Ill.
ECKERT, EDWARD WILLIAM...........105 West 64th St., New York City.
FILLEY, HIEL HAMILTON..............1326 Forest Ave., Kansas City, Mo.
FOLLETT, WILLIAM W................Cons. Eng. International (Water) Boundary Comm., U. S. and Mexico, El Paso, Texas.
GIBBS, CHARLES WINGATE.............Telluride, Colo.
LUCIUS, ALBERT.......................Room 87, 38 Park Row, New York City.
NEARING, FRANK......................Care of Imperial Hotel, 5 Exchange Place, Jersey City, N. J.
QUIMBY, HENRY HODGE...............Chf. Eng., Phœnix Iron Works, Phœnixville, Pa.
SPILSBURY, EDMUND GYBBON..........45 Broadway, New York City.
WILLIAMSON, FRANCIS STUART.........Room 306, 99 Cedar St., New York City.

ASSOCIATE MEMBERS.

LENTILHON, EUGENE.................5 Bowling Green, New York City.
MONTONY, LIBERTY GILBERT..........21 West 32d St., New York City.
POULSTON, ARTHUR EDWIN............Butler, Pa.
WALKER, JOHN SHAW.................21 Croydon St., Petersham, Sydney, N. S. W.

JUNIORS.

BRIGGS, WALDO CLAYTON ....21 Granite St., New London, Conn.
MAGOR, HENRY BASIL................109 West 70th St., New York City.
NYE, ALGERNON SIDNEY.............Oak Ridge Club House, Kingsbridge, N. Y.
RITTENHOUSE, HARVEY...............Box 122, Shenandoah, Va.
TRAVELL, WARREN BERTRAM..........Gen. Foreman, Bureau of Streets and Roads, 415 West 123d St., New York City.

ADDITIONS TO

LIBRARY AND MUSEUM.

From American Society of Irrigation Engineers, Denver, Colo.:
Transactions, Vol. II, No. 3. January, 1897.

From Belgian Society of Engineers, Brussels, Belgium:
List of Members, 1896-97.

From Walter G. Berg, New York, N. Y.:
Discussion on "The Profession of the Railway and a Suggested Course of Training Therefor."

From Board of Regents of the Smithsonian Institution, Washington, D. C.:
Annual Report for the year ending June 30th, 1894.

From Board of Trustees of the Sanitary District of Chicago, Chicago, Ill.:
Proceedings, February 3d, 10th, 17th and 24th, 1897.

From John Bogart, New York, N. Y.:
Chemin de fer Métropolitain de Paris, Traction.
Traction au Moyen des Locomotives à Vapeur sans Feu, Système Lamm et Francq.
De la Traction du Métropolitain.
De la Valeur Théorique et Pratique des Moteurs à Air Comprimé.
Les Locomotives sans Foyer; leur Application aux Tramways Mexicains.
Compagnie des Tramways du Département du Nord (Les Locomotives sans Foyer, Système Lamm et Francq).
Compagnie Continentale d'Exploitation des Locomotives sans Foyer (Mémoire sur le Système Lamm et Francq).
Les Locomotives sans Foyer (Plate from Portefeuille des Machines).
Journal of House of Reps., Pa., 1829-30, containing report on Allegheny Portage.

From British Association for the Advancement of Science, London, Eng.:
Report of the Sixty-sixth Meeting, at Liverpool, 1896.
Preliminary Programme of the Toronto Meeting, 1897.

From Canadian Society of Civil Engineers, Montreal, Can.:
Transactions, January to June, 1896.

From Arthur P. Davis, Washington, D. C.:
Report on the Irrigation Investigation for the benefit of the Pina and other Indians on the Gila River Indian Reservation, Arizona.

From Mordecai T. Endicott, Washington, D. C.:
Appendix to the Report of the Board of Engineers for the Purpose of Ascertaining the Feasibility, Permanence and Cost of Construction and Completion of the Nicaragua Canal by the Route contemplated and provided for by the Act which passed the Senate, January 28, 1895. Doc. 279, Part 2, House of Representatives.

From Engineers' Club of Cincinnati, Cincinnati, O.:
Secretary's Report and List of Members, December 17, 1896.

From Engineer Commissioner, Washington, D. C.:
Report of the Operations of the Engineer Department of the District of Columbia for the year ending June 30, 1896.

From J. V. Mendes Guerreiro, Lisbon, Portugal.:
Obras do porto de Lisboa.

From Harbor and Land Commissioners, Boston, Mass.:
Annual Report for the year 1896.

From H. A. Hazen, Washington, D. C.:
The Tornado.

From D. Ferrand Henry, Detroit, Mich.:
A Link in the Chain. A Ship Canal between Lake St. Clair and Lake Erie.

From Edwin A. Hill, Washington, D. C.:
Report of the Commissioner of Patents for the calendar year ended December 31, 1895.

From Institution of Mechanical Engineers, London, Eng.:
Proceedings, April, 1896.

From Iron and Steel Institute, London, Eng.:
The Journal, Vol. L., 1896.

From William Jackson, Boston, Mass.:
First Annual Report of the Water Commissioner (Boston, Mass.), for the year ending January 31, 1896.

From S. P. Langley, Secretary, Washington, D. C.:
Smithsonian Miscellaneous Collections. A Catalogue of Scientific and Technical Periodicals, 1665-1895.

From Association Amicale des Anciens Élèves de l'École Centrale des Arts et Manufactures, Paris, France:
Annuaire, 1832-1896.

From Patent Office, London, Eng.:
Abridgments of Specifications of Patents for Inventions, Fastenings, Lock, Latch, Bolt and Other; Paints, Colors and Varnishes; Bearings and Lubricating Apparatus; Drying; Tobacco Boxes and Cases.

From S. F. Patterson, Secretary, Concord, N. H.:
Proceedings of the Sixth Annual Convention of the Association of Rail-

way Superintendents of Bridges and Buildings, held in Chicago, Ill., October 20th, 21st and 22d, 1896.

From H. V. and H. W. Poor, New York, N. Y.:
Poor's Manual for 1896.

From Reform Club, Committee on Municipal Administration, New York, N. Y.:
Municipal Affairs, Vol. 1, No. 1.

From Gustave Richard, Secretary, Paris, France:
Revue de Méchanique, Vol. 1, No. 1.

From Royal Institute of Engineers, Hague, Holland:
Notulen der Vergaderingen, Tweede Aflevering.
Verhandelingen, Vertalingen, etc., Tweede Aflevering.

From Society of Civil Engineers of France, Paris, France:
Inauguration du Nouvel Hotel de la Société le 14 Janvier, 1897.

From U. S. Department of Agriculture, Forestry Division:
Bulletins Nos. 6, 7, 10, 11 and 14. Timber Physics; Forest Influences; Timber, an Elementary Discussion of the Characteristics and Properties of Wood; Some Foreign Trees for the Southern States; Nomenclature of the Arborescent Flora of the United States.

From U. S. Department of Agriculture, Office of Road Inquiry:
Bulletins No. 11 to 20. Circulars No. 14 to 26.

From U. S. Department of the Interior:
Report on Vital and Social Statistics in the United States at the Eleventh Census, Part 4.

From U. S. Geological Survey:
Magnetic Declination in the United States.

From U. S. National Museum:
Annual Report for the year ending June 30th, 1894.

From U. S. Patent Office:
Alphabetical Lists of Patentees and Inventions for the Quarter ending September 30th, 1876.
Index to Official Gazette, July to September, 1896.

From U. S. Treasury Department, Bureau of Statistics:
The Foreign Commerce and Navigation of the United States for the year ending June 30th, 1896. Volume I.

From U. S. War Department, Chief of Engineers:
Forty-two Reports on the Improvement of Certain Rivers and Harbors.
Fifteen Specifications for the Improvement of Certain Rivers and Harbors.
Annual Report of the Chief of Engineers, U. S. Army, 1896. 6 vols.

From University of Pennsylvania, Philadelphia, Pa.:
Catalogue, 1896-97.

From University of the State of New York, Albany, N. Y.:
Extension Bulletin No. 16, October, 1896.

From Horace G. Wadlin, Boston, Mass.:
Twenty-sixth Annual Report of the Bureau of Statistics of Labor, March, 1895.
Annual Statistics of Manufactures, 1895.

From Herbert M. Wilson, Washington, D. C.:
Water Supply and Irrigation Papers of the United States Geological Survey, No. 1, Pumping Water for Irrigation.

From G. S. Williams, Detroit, Mich.:
Forty-fifth Annual Report of the Board of Water Commissioners (Detroit, Mich.), for the Year 1896.

Source unknown:
Deep Water Harbor in Southern California, Port Los Angeles *vs.* San Pedro. Full Report of Oral Testimony at Public Hearings in Los Angeles, December, 1896.

1897. MARCH. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS:

VALUATION OF WATER-WORKS PROPERTY.

BY WYNKOOP KIERSTED, M. Am. Soc. C. E.

TO BE PRESENTED APRIL 21ST, 1897.

The question of determining the value of water-works property is one of much significance in view of the approaching expiration of many water-works franchises. It involves the probable purchase of the property by the city or the renewal of the contract with the private water company for another term of years. It is a question which engineers are called upon to consider in all its practical bearings, and therefore becomes a proper question of discussion among them.

Briefly, the situation is this: Many cities have granted to private water companies franchises to construct, operate and maintain systems

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meetings, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

of water-works for a specified term of years. The duration of the franchise in most recorded instances is from twenty to thirty years, occasionally for fifty years, and in a few other instances, for ninety-nine years, or is a perpetual franchise. It is recorded of some franchise ordinances that no time is fixed for the purchase of the property by the city, of others that the property may be purchased at any time or at fixed intervals. A few ordinances may specifically name a price to be paid for the property or may state that the cost of the plant or property is to be the basis of purchase; but in many, if not most, instances the ordinance defines the purchase-price to be the value of the property as determined by disinterested appraisers or arbitrators, and defines in a general way the method of appraisement. The terms of the franchise ordinance may name certain rates to be charged consumers of water and make them subject to modification from time to time; or they may fix a schedule of rates which shall not be exceeded; or they may leave the rates altogether unregulated.

Years roll by. The franchise and attendant contract are about to expire. The city contemplates a purchase of the property, or the private water company must have a new franchise if it is to continue to maintain and operate the water-works plant. In the event of a purchase by the city, the company and the city must agree upon the value of the plant, if this value be not already fixed by the terms of the franchise ordinance. The method of appraising the value as defined in the franchise ordinance may or may not work satisfactorily. That depends on the real desires of either or both parties to the contract to reach an agreement. In the event of a disagreement and a resulting controversy, a third party may intervene to arbitrate the differences and to fix upon a value of the property. If the decision of the arbitrator or arbitrators be not accepted as final, then the power of the court may be invoked to determine the matter and to enforce, if necessary, the terms of its decision.

In the presentation of evidence before arbitrators, commissioners or courts, the engineer is often called in as an expert witness, and sometimes as an arbitrator or a commissioner. Upon occasions of this kind the evidence of experts relating to valuation may be more or less conflicting, because of the nature of the instructions from their respective clients, or because of the efforts of one or the other of the contestants to strengthen some assumed position or to prove some

abstract proposition by means of a certain line of testimony, or because of the possession of incomplete data upon which to base an opinion, or yet because of a difference in conception on the part of the several individuals as to the proper basis upon which to estimate the value or cost.

If the mere question of cost of the plant be involved, a bare showing of the construction and maintenance accounts should suffice ; but if the value of the property be sought, the problem becomes different altogether. The cost of an article is the amount actually paid for it. The cost of a plant is the amount expended in constructing it. The cost of a property is the amount expended in constructing and establishing it.

Value is a measure of utility, or the amount which can be obtained in exchange. It depends upon the cost of production and the relation between supply and demand, tending to become fixed when the cost of production is constant, or when the supply and demand are equal; to decrease when the demand is less than the supply, and to increase when the supply is less than the demand. If the production of an article be limited and a general and constant demand for it exist, there is a tendency towards a constant rise in value which eventually confines the sale to those arts or industries absolutely requiring the use of it or to the gratification of the wants of those who can afford it. With a supply unrestricted except by conditions of demand and with a normal demand, the market price of an article may progressively decline as the result of improved facilities of manufacture and transportation. Thus the price of pig iron in 1878, a year of great depression, averaged \$15 73 per net ton. During the boom of 1880 it suddenly rose to \$36 60 per net ton, and more suddenly fell to \$20 50 in the same year, after which the price remained steady at \$21 43 and \$23 21 for about two years, and then gradually declined in 1883, 1884 and 1885 to \$16 per net ton, which was the average for 1885. In the exceedingly active year for the iron trade, 1886, the average price for the year was only \$16 74. This reduced price, which even a brisk trade and large demand for iron could not advance, was the result of improved facilities of manufacture and transportation. However, the producer received his legitimate profit through sales at the low price just as he did at the high price. He who purchased the production of pig iron for some specific purpose, as for use in a water-works

plant, at the high price prevailing in 1879 and 1880, would possess a plant which cost more than one of equal magnitude and capacity constructed in 1886, and still more than one constructed in 1895 when the price of pig iron was about $9 per net ton. Therefore he who built a water-works in former years, when the prevailing prices of material were high, should have aimed to adjust the income accruing from the operation of the plant so that it would return him, not only his current expenses and legitimate profit, but an amount of money representing a progressive decrease in the cost of constructing a similar plant, in order that he might be able to adjust water rates to meet the competition which would indirectly result from the operation of similar plants constructed in the same locality in later years under more advantageous circumstances, and affording the same margin of profit as he had established. Otherwise he might find himself oppressed by outside influences, or forced to operate the plant at a personal loss, or to dispose of it as an unprofitable investment at a price controlled more or less by the current price of materials, instead of by original cost.

It is, of course, impossible to anticipate the various causes and complications which may serve to depreciate the material value or earning capacity of a water-works, or the extent their effects may be offset by the appreciating effect upon the value of such a property of a more perfect administration and more economical methods of delivering a suitable water supply to consumers of water. Still they must be anticipated in a measure to insure success, with due consideration for the twofold aspect which attaches to value and valuation. For, on the one hand, the value of a water-works property to an investor is dependent upon its ability to produce net revenue, and upon freedom from interference from those causes which may influence the standard or schedule of prices upon which the revenue is dependent. Any change in the schedule of water rates or in the fixed rates of payment contracted for, as, for instance, hydrant rentals, affects the amount of revenue, and, proportionately, the value of the plant. On the other hand, the consumer, individually or collectively, receives and pays for, not only water from the pipes of the water-works, but also for a certain amount of service utilized in the delivery of the water, and his ideas of the value of the property are more or less colored, and properly so, by the character of the service and the quality of the

water. If both the service and the water are satisfactory, the charges for the water service are subject to little or no objection on the part of the consumer so long as they remain fair and indiscriminating, thus affording a stability to the value of the property, which could not obtain in an atmosphere of contentious and antagonistic public sentiment resulting from an inefficient water-service.

There is also an element of risk attached to the building up of a successful water-works property, which it is difficult to define or limit. The possessor of a water-works franchise expects to derive some pecuniary advantage from the operation and maintenance of a water-works conducted in pursuance of the terms and requirements of the franchise. At the outset he cannot anticipate with any degree of precision the direction of the growth or the magnitude of the expansion of his property. That will depend very much upon the commercial importance eventually attained by the city in which he exercises his franchise rights. He realizes that if he builds at the outset only for the present, and progressively expands the plant to meet a growing demand, then eventually the plant in its entirety will cost more money than would suffice to duplicate it in a single process of construction. He also realizes, on the other hand, that speculations as to future requirements may eventually prove erroneous, and that investments to meet a future demand must be supported until actually demanded by such expenditures as may become necessary, whether the revenues accruing from the operation of the plant be or be not available for that purpose. Under most circumstances the business policy governing private investments which are attended with the least financial risk, particularly if the franchise inviting the investment be restricted to a comparatively short term of years, would confine the investment largely to the actual requirements of the case. But the risk does not end here; for before the franchise shall have expired, the developments of a city and its immediate surroundings may create a new set of conditions which may compel, as they sometimes do, the selection of a new source of water supply and a modification of the plan which has controlled previous expenditures. Enforced changes of this character and magnitude, wholly unanticipated, as they often are, entail heavy expenditures without proportionately increasing revenues. They may even require the abandonment of portions of existing works, and are usually attended by many complications and incidental expenses. Such a hazard as

described can scarcely be avoided, and this hazard, together with the circumstances under which it is assumed, should be considered in connection with the process of valuing a water-works property in its entirety.

The early efforts of the management of a water-works property to induce the public or the individual to exchange the "moss-covered bucket" for the faucet, and to build up an extensive patronage while rendering efficient service, may result in financial loss during the first few years of existence. Such losses, together with interest paid upon money expended during the interval of construction of the works, are considered by the investor as a part of his invested capital and an item of original cost of construction. Such expenditures, properly made, might be less under the management of a private water company than under that of a city, because of the more direct and expeditious manner in which the former often accomplishes the desired ends, but they certainly constitute a legitimate expense which anybody, city, company or individual, building up a business of water purveyor, must incur, and for which there should be in some manner a resulting compensation. Therefore, the original cost of construction would not and could not control the value of the plant to the investor. That value may be less or more than its original cost. Of course, to the management the minimum value of its plant is the total outlay up to the time the plant becomes self-sustaining. To a purchaser, however, the value of the plant previous to its becoming self-supporting and based upon net revenues, would be less than cost, or, based upon the prospective value of the property, would be altogether speculative. But a speculative purchase will in most instances be confined to the earlier years of the existence of a franchise, and a speculative purchaser must be responsible for any errors of his own judgment and either gain or lose by the transaction as the value of the works eventually expands or shrinks.

The most important occasion calling for a valuation of water-works property is the one incident to the purchase by the city through the exercise of its option to purchase at stated intervals or at the expiration of the franchise. The choice of a basis for the valuation of such a property affords an opportunity for the expression of a variety of opinions. The author has heard it asserted that an appraisement of value should be made by capitalizing the gross earnings less the oper-

ating expenses; or by capitalizing the gross earnings after deducting the operating and maintenance expenses ; or that the original cost of construction constitutes an important element in determining the proper value; or yet that the cost of duplicating the works less depreciation is the only just basis of valuation.

The question of depreciation of materials of construction through the effects of age and use, whenever considered in connection with valuation, admits of a wide range of judgment. For instance, the useful age of cast-iron water pipe has been variously estimated from twenty-five to sixty years, or even more. Probably the basis of estimate in the several instances was experience in the use of cast-iron pipe in as many localities, and the judgment may have been correct for those localities. However this may be, a definite period of usefulness cannot be arbitrarily fixed for general application without more or less partiality and error. It is certain that some soils will cause more rapid deterioration of cast-iron pipe than others, and that inferior workmanship and materials of manufacture also increase the rate of deterioration. Whenever the opportunity offers, the probable life of metallic or other structures should be estimated specifically for each locality by observation of the local effects of those agents and conditions promoting deterioration, but this life may, in a measure, depend upon other conditions than deterioration by mere wear and tear.

In some instances of valuation the small pipe of a water-works system has been rejected as practically useless, but it is difficult to see the justice or consistency of rigid discrimination of this character. It is true that errors of design and construction, which impair the efficiency of the plant or the service, or necessitate the abandonment of certain portions of water-works, should be taken into account in appraising the value of such property. Upon these occasions the appraiser should discriminate between deliberate errors for speculative purposes and errors enforced because of insufficient funds, or errors which simply became apparent through the development of conditions or environment which could not have been anticipated. The use of small pipe is often enforced economy. Though sound engineering practice, in view of the highest practicable efficiency of general water service, may, upon many occasions, reject small pipe, still financial considerations often compel the temporary use of it in limited amounts. Therefore, a process partaking largely of a business char-

acter, such as is the appraisement of the value of property, should not neglect to consider the value of a certain class of construction or service to the full extent of its usefulness, even though below the highest standard of excellence, provided such consideration be not in conflict with explicit and practical contract stipulations.

It is now in order to discuss briefly each method of valuation as suggested with a view of reaching some basis of valuation which is just and equitable. Of course, the specific requirements of the franchise and contract must be regarded, but vague statements and technical interpretations of any contract should not affect its impartial bearings upon important points. In this discussion, a few illustrations may serve to make the remarks more concise and explicit; therefore, reference is made to the Kansas City, Mo., and the Syracuse, N. Y., cases as developed in recent litigation.

The following quantities and amounts are the average for the year 1893 in Kansas City, Mo., as given by the National Water-Works Company in its testimony before the courts in its late controversy:

Gross earnings for Kansas City, Mo., water-works	$391 464 29
Total operating expenses for Kansas City, Mo., part of plant	106 700 87
General expenses reported from New York	12 000 00
Net earnings in Kansas City, Mo	272 763 42
Cost of a system of water-works for Kansas City, Mo., as estimated by board of experts employed by the city	2 002 434 50
Worth of plant, 1893, as estimated by commissioners appointed by the court	1 330 000 00

Value Deduced from Gross Earnings.—The net earnings of the Kansas City plant are shown to be $272 763 42. The rate of interest which a private company often expects on investments in water-works properties and in water-works securities is 6 per cent. Therefore $272 763 42 capitalized at 6% amounts to $4 546 057. Had Kansas City purchased at such a valuation, the revenue from the sale of water would have had to provide for the following expenditures:

Operating and local administration expenses, as given by water company........................	$160 700
Interest on $4 546 057 at $4\frac{1}{2}$ per cent...............	204 573
Sinking fund at $4\frac{1}{2}\%$ to extinguish the debt in 20 years..	144 883
Total................................	$456 155
The gross earnings for Missouri were, in 1893, $391 464 42; from this deduct hydrant rental to water company, $76 000. There remains $315 464, the gross revenue-producing ability of the plant as turned over to the city; hence deducting....................................	$315 464
There remains an excess of expenditures of........	$140 691

The water-works to be self-supporting must therefore have the revenues increased nearly 45% by a general advance of all water rates. Kansas City water rates are already high, and an advance of 45% would necessarily render them burdensome. This basis of valuation, although advocated by the water company in the late controversy, is manifestly unfair, as it requires an immediate advance of high rates to support the investment. It conclusively shows an over-valuation.

Value as Determined by Capitalizing Gross Earnings, after Deducting Operating and Maintenance Expenses.—By this method, from the gross earnings of the plant should be deducted the operating expenses, which embrace labor, supervision, cost of collection, fuel, supplies. and repairs necessary to keep the works in operation, also the maintenance expenses, which embrace a sinking fund which would equal in amount the original investment after a term of, say, twenty years. To illustrate:

Let x equal the capitalized value of a water-works property.

$\frac{6\,x}{100}$ = Annual interest at 6 per cent. upon the capitalized value.

$\frac{a\,x}{1\,000}$ = Sinking fund, where a represents the annual contribution to the sinking fund per $1 000 at a given rate of interest.

Hence:

$\frac{6\,x}{100} + \frac{a\,x}{1\,000} =$ The net earnings, or the amount left after deducting operating expenses from gross earnings;

or $x =$ the net earnings multiplied by 1 000 and divided by $60 + a$.

As has been stated, an ordinary rate of interest for private corporation securities is 6 per cent. The rate of interest which an investment of sinking fund will draw is somewhat indefinite, but it will probably vary between 4 and 6 per cent. At 4% the annual contribution to the sinking fund would be \$33 58 per \$1 000; at 4½%, \$31 87; at 5%, \$30 24; and at 6%, \$27 18.

It has been stated that the net earnings of Kansas City, Mo., waterworks, after deducting the operating expenses, are \$272 763 42, hence:

$$\frac{6\,x}{100} + \frac{a\,x}{1\,000} = \$272\ 763\ 42, \text{ or } x = \frac{\$272\ 763\ 420}{60 + a}$$

With a sinking fund at 4%, $x =$ \$2 905 000
" " " 4½%, $x =$ 2 969 000
" " " 5%, $x =$ 3 023 000
" " " 6%, $x =$ 3 128 000

What would be the annual cost of operation to the city, based upon the above valuation?

Assume a sinking fund at 4 per cent.

Operating expenses	\$106 700
Interest at 4½% on \$2 905 000	130 725
Sinking fund at 4% to pay off \$2 905 000 in twenty years	97 550
	\$334 975

Sinking fund at 4½ per cent.

Operating expenses	\$106 700
Interest at 4½% on \$2 969 000	133 605
Sinking fund at 4½% to pay off \$2 969 000 in twenty years	94 622
	\$334 927

Sinking fund at 5 per cent.

Operating expenses	$106 700
Interest at 4½% on $3 023 000	136 035
Sinking fund at 5% to pay off $3 023 000 in twenty years	91 414
	$334 149

Sinking fund at 6 per cent.

Operating expenses	$106 700
Interest at 4½% on $3 128 000	140 760
Sinking fund at 6% to pay off $3 128 000 in twenty years	85 019
	$332 479

In all probability, a large and prosperous city can borrow money at 4½%, and under the usual legal restraint would scarcely realize more than 4 to 5% upon investments of the sinking fund. Upon this basis a valuation of $3 000 000 in round numbers would result. This is the value fixed for the property by the court of final resort in the case.

Next take another illustration quite as much to the point as that of the Kansas City water-works, viz., the appraisement of the value of the Syracuse, N. Y., water-works.*

This property was appraised by three commissioners, appointed by the court, who heard much testimony from experts representing both sides of the controversy. The testimony on the part of the water company showed the plant to have cost $900 000. In other words, that that amount of money had been expended upon it. The profit and loss account showed a net revenue of $70 000 per annum over and above all charges. The city's experts estimated the present value of the plant at $391 030, after deducting from their gross estimate amounts representing depreciation of material and the cost of bringing the plant to a standard of efficiency considered proper by the city's experts. The present value of the plant was estimated by the company's experts at $852 775. Neither estimate included any real estate.

* The data are taken from an interesting article presented to the American Water-Works Association in 1893, by Mr. S. E. Babcock, giving an account of the methods and results of the appraisement of the water-works property owned by the Syracuse Water Company at a time when the City of Syracuse desired to become possessor of the property.

The bonded debt of the company was $200 600.* Upon this amount of money an annual interest at 6% is $12 036; hence, $12 036 added to $70 000, the net revenue after deducting all charges, gives $82 036 as the net revenue after deducting operating expenses.

Now, $x = \frac{\text{Net earnings} \times 1\,000}{60 + a}$. If a be taken as annual contribution to the sinking fund at 4%, perhaps a fair rate of interest for the East, then $x = \frac{82\,036\,000}{60 + 33.58}$ or $x =$ $876 640, representing the value of the water-works property. The value appraised by the commissioners was $850 000. The report of the commissioners was confirmed by the court, and the award paid by the city.

This method of appraisement may be objected to upon the ground that the assumption of 6% as the interest upon the investment and the 20-year limit to the franchise are altogether arbitrary. In the appraisement of value based upon earning capacity, the assumed rate of interest should be that usually paid upon private corporation securities rather than upon municipal securities, because the water rates are established with a view of paying interest on that class of securities. Moreover, there is no valid reason why the water company should be benefited in the appraisement of the values of its property by a consideration of a city's ability to borrow money at a less rate of interest than itself. Six per cent. is the usual rate of interest paid for money loaned upon private water companies' securities, especially among the central, western and southern states. Because of the discount at which such securities are frequently sold, the income may net the investor more than 6%, yet this is offset very often by the expense the investor incurs in defending or protecting his investment.

If a period of 30 years instead of 20 years were assumed as a duration of the franchise, then for any fixed net revenue the annual contribution to the sinking fund would become less, and the valuation of the water-works property would proportionately increase; for example, with a net revenue of the Kansas City works of $272 763 42, and the annual payment into the sinking fund of $16 40 at 4½%, to extinguish the purchasing debt in thirty years, the valuation of the property by the method outlined would become $3 570 000 instead of $2 969 000 as determined for a period of 20 years. For a similar rea-

* See the "Manual of American Water-Works" of 1891.

son, for a period of less than 20 years the valuation would be proportionately decreased; but, on the other hand, any time limit to a bond of less than 20 years renders it scarcely marketable with success at a low rate of interest. Therefore, the income based upon the established schedule of water rates should, at least, support an investment of this duration and character, approximating the cost of constructing, establishing and supporting the water-works property. It is scarcely advisable to consider a longer period than 20 years, because by or before the expiration of that interval much of the machinery in current use may have become antiquated, worn out, or inadequate to meet the demands made upon it; or the distribution system of pipes may have become of insufficient capacity, to a greater or less extent, requiring reinforcement or renewal of those portions of it which may have been rendered useless from other causes than mere deterioration through ordinary wear and tear; or yet the development of the city during the interval may require a modification of the plan of water-works, or a change of water rates in order to adjust revenues to a new set of conditions. Moreover, it is probably advisable for the present generation to share with the future generation the expense of developing and establishing a system of water-works.

The method of valuation, as outlined under the second case, appears fair and equitable, provided that at the time of purchase or appraisement the plant is in good condition and renders efficient service throughout the territory included by the distribution system of pipes, and that the schedule of water rates is a fair and reasonable one.

Original Cost as an Important Element in the Valuation of a Water-Works Property.—After the preliminary remarks of this paper it is indeed difficult to define in what manner the original cost of a water-works plant can affect its value after a protracted term of service. It has been indicated that any well-managed water-works property should have anticipated at the time of construction a more or less permanent and gradual decline in the prices of materials of construction, and should have gauged and utilized its revenues accordingly. Undoubtedly any and every successful water company has done so, and thus maintained its ability to compete in the sale of water at all times and at any reasonable water rate.

The accounts of construction of the management of a property are the only authentic source of information upon original costs. As a

rule, such information is withheld from scrutiny, largely, perhaps, because the amount of bonds and stocks issued against the property is measured more by the revenue-producing ability of the plant than by its actual cost; and the management desires an appraisement to equal, at least, its indebtedness. Therefore, to expose the actual cost of the plant would tend to militate against its own interest. Again, a city or anyone purchasing a water-works at a time when the franchise has nearly expired would scarcely be willing to pay even its actual cost if the revenues therefrom would not support the investment, and it is unreasonable for a purchaser to expect to obtain a profitable and established business and plant at its material value. This basis of valuation does not appear equitable to all parties concerned, as it leaves out of consideration other elements affecting valuation, and could scarcely obtain, unless it had been accepted by contract as the most desirable basis of valuation.

Cost of Duplication as a Basis of Valuation.—Those arguing the equity of this basis of valuation claim that the management of the works during the existence of the franchise should have received back the original capital invested, and that all that it is entitled to at the expiration of the franchise is the material value of the plant. Doubtless any investor would be satisfied with a final settlement of that nature were he amply assured of or guaranteed the return of the capital invested in the works from time to time, together with interest. Such a guarantee would then involve comparatively little risk on his part, as he would ultimately be subjected to no loss because of modification or reduction of water rates and prices for water service, or because the schedule of water rates did not admit of full return of his investment with interest during the existence of the franchise, or because of losses by unforeseen accidents and other contingencies. No city could afford to make such a guarantee, as it would tend to place a premium upon extravagant management. It would be impossible to fix at the outset a schedule of water rates which would insure the desired income. Moreover, the city would be obliged to accept finally the statement of the investor as to the amount of his investment or assume discretionary power with respect to the amount and character of expenditures, which proceeding is in effect equivalent to a city borrowing money and building its own works. No one would expend money on an investment of this kind while assuming all risk incident to the building up of a profitable

business, and to the return of the invested money with interest within a limited time, and in the end accept almost a scrap value for the plant and business. It would be unreasonable to expect the management of a water-works property to do so, as it should be entitled to reimbursement for proper efforts and expenditures necessary in the building up and maintenance of a profitable business; and a city should be willing to take this view of the case, as upon acquiring the property it is benefited by having most of the many doubtful and uncertain problems worked out, and starts out to collect revenues accruing from a developed and systematized business. The author sees no practicable way of directly estimating the value of such service, except by appraising the value of the plant and business as a whole upon a fair and equitable basis.

However, though the cost of duplication, less depreciation for wear and tear, of a plant may not of itself constitute a fair valuation, still it may be taken as a suitable starting point from which to estimate the value of a property as a whole. As an illustration, the Kansas City water-works plant was estimated by commissioners to have a present worth of \$1 330 000 00.

Let $x =$ the capitalized value of property.

Let $x + \$1\ 330\ 000 =$ the total value of the property,

Let $\frac{(x + \$1\ 330\ 000)\ \$31\ 87}{1\ 000} =$ sinking fund which at $4\frac{1}{2}\%$ interest would equal $x + \$1\ 330\ 000$ at the end of 20 years.

Let $\frac{6}{100}(x + \$1\ 330\ 000) =$ interest upon total value of property at 6 per cent, hence $\frac{6}{100}\left(x + \$1\ 330\ 000 + \frac{(x + \$1\ 330\ 000)\ \$31\ 87}{1\ 000}\right) =$ \$272 763 42, the net revenue; $x = \$1\ 639\ 000$, the capitalized value.

The total value of property equals \$1 639 000 + \$1 330 000 or \$2 969 000, an amount agreeing, as it should, with the value determined by the second method with the sinking fund at $4\frac{1}{2}$ per cent.

There is another aspect to this question of valuation of water-works property which it is important to consider. A water-works franchise is naturally exclusive and frequently restrictive. It is exclusive because the heavy cost of constructing, operating, and maintaining a water-works plant practically excludes successful competition in the same territory covered by the said franchise. Often it is restrictive because in view of the lack of opportunity to control water

rates through ordinary channels of commercial competition, a schedule of water rates considered fair and equitable fixing the charge for water, or a maximum charge, is made a part of the franchise ordinance. Thus a water company may without foreign interference realize such, and only such, profit from the operation of the water-works as the established schedule of charges and the prudence of its management may admit. The net earning capacity of the property measures its value to the owner. At the same time, a city granting a franchise of this character to a private water company accepts an option to purchase the water-works property at stated intervals, or obligates itself to purchase it at a certain time at an appraised value, and binds itself to recognize an established schedule of water rates which, having been mutually agreed to, must have been considered fair and equitable. It is, therefore, difficult to see how a city can escape the obligations imposed by its own legal acts, which in effect legislate a value to a property that it expects or obligates itself to purchase eventually.

In conclusion it is clear that the original cost or the bare cost of duplicating a water-works property is not of itself a measure of the value of that property. Its present value embraces both the value of the plant and the business resulting from the use of the plant. Together they constitute a single commodity. Therefore, in an appraisement of value of water-works property, it is the commodity which is appraised, and not the materials of construction. If a city purchase such a plant, after having once, or upon several occasions, fixed or modified the schedule of water rates, thus through legislation establishing a maximum value to the property, it should evidently pay its commodity value unless the contract specifically state otherwise, or unless it be prevented by superior authority. This value is affected both by the ability of the property to produce net revenue and by the contract requirements relating to the structural features of the plant. As a commodity such a property may receive a fair and equitable valuation when based upon a net revenue derived from the sale of water resulting from the operation of a fair schedule of water rates, and when the structural details and the efficiency of service conform to reasonable contract requirements. Should the water rates be excessive or even fair, and the construction, the materials, or the service of inferior quality, then the value of property appraised upon a net

earning basis without proper deductions may become proportionately excessive.

Thus Case 2, or, what is practically the same, the latter part of Case 4, constitutes, the author believes, a process of fairly and equitably estimating the value of a water-works property; provided the schedule of water rates be not excessive and deductions be made from the amount so determined sufficient to cover the cost of bringing the plant to the condition of efficiency reasonably contemplated by the contract, if found inefficient. When water rates are unregulated by the terms of the franchise ordinance, as they are in some instances, the citizens should have some legal resource to protect themselves from extortionate charges.

These details should be considered in renewing a contract with a water company, for, if the hydrant rentals or the schedule of water rates be fixed too high, it offers security for an investment in excess of that necessary to operate and maintain properly an adequate system of water-works and an efficient water service, and thus gives the property a somewhat abnormal market value. On the other hand, there is no advantage in attempting to establish a schedule of water rates which will afford an inadequate return upon a reasonable valuation of water-works property, as it will result in a more or less inefficient service. A schedule of charges adjusted to the conditions prevailing at the time of the original installation of a water-works plant may not apply with the same degree of equity after the expiration of a considerable interval of time when the commercial prosperity of a city shall have become better established and the character and direction of improvement and expansion more fully defined.

The author admits the existence of elements of uncertainty in the work of adjusting equitable water rates. Independent efforts to formulate originally an equitable schedule of water rates for any town would perplex even the mind of an expert in such matters. The element of uncertainty accompanying work of this character can only be eliminated in individual instances by trial and by modification of water rates as the contingency arises, or through the assistance derived from a judicious study of the workings of established schedules of water rates in towns requiring a similar treatment of the water supply problem as the town in question. It is unfortunate that some water-works managements are not in position or are not inclined to equip

their property with the necessary facilities to furnish a wholesome water, free from the evidences of pollution and above suspicion of infection, because of an abnormally low schedule of water rates or because of abnormally high debt or capitalization which the income from the sale of water is called upon to support. These discrepancies must soon be eliminated in order that the standard of quality of public water supplies may be elevated to meet the rapidly growing popular demand for better and more wholesome water. So long as they obtain they constitute an element to be considered in the valuation of the water-works properties. The establishment or modification of a schedule of water rates must include the consideration of the present or proximate future necessity of having to purify the water drawn from rivers and similar sources of water supply susceptible of pollution; for it is only a question of a very short time when there will prevail throughout the country a more or less imperative demand for the employment of better safeguards for the public health. It is an established fact that typhoid fever, cholera and diarrhœal complaints are pre-eminently water-carried diseases. Already the death rate from typhoid fever in this country is high, increasing directly, in very many instances, with the degree of pollution of the water supply, and there is a well-developed movement afoot to abate inroads of this disease by the employment of practical agencies to eliminate as many of the sources of infection as possible. Experience has proved that proper sand filtration is a very effectual defence against infection through drinking water, especially for those cities which are unable to procure a suitable supply of water from sources exempt from pollution by organic matter. Therefore, in many instances, the establishment of water rates should anticipate a revenue to support filtration subsequent to sedimentation in basins, in connection with other concomitants to a pure and wholesome water supply.

Finally, the question may be raised as to how, in the event of the valuation of a water-works property being based upon its earning capacity, it shall be known whether the schedule of water rates in current use is equitable, inasmuch as an equitable rate is necessary to the fixing of a fair valuation upon the property. To this question the author would reply that those towns which obligate themselves to purchase a system of water-works at its appraised value, and which fix by ordinance a schedule of water rates to apply during the life of

the franchise without reserving to themselves the power to modify or to compel a modification of them, can scarcely escape the penalty of having to purchase the property at an inflated value if the rates be fixed too high, except through incapacity of the plant, or by concession on the part of the owner, or through evidence submitted by him showing the income accruing from the operation of the water-works to be less than that which the maximum charge under the schedule of rates would afford. In this instance the question whether the established schedule of rates is or is not equitable does not obtain, but is rather what is a fair valuation of the property based upon a given schedule of charges. A city, which not only fixes a schedule of water rates, but also reserves the power to regulate them within equitable limits, or to enforce such regulation, can prevent extortionate charges, and can insure the establishment of a fair schedule of charges previous to the expiration of the franchise or to the date of purchase. Towns without the authority to fix or regulate water rates, and those having established a flexible schedule of rates fixing maximum charges, can hope to arrive at a fair valuation of the property only through proper evidence bearing upon its efficiency and earning capacity.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will hereafter be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

JAMES LAURIE, Past-President Am. Soc. C. E.*

DIED MARCH 16TH, 1875.

James Laurie, the first President of the American Society of Civil Engineers, was born at Bells Quarry, near Edinburgh, Scotland, on May 9th, 1811. He lived in Scotland for some time, and once, during his boyhood, when hurt through some accident, was found by Sir Walter Scott, who was out fishing. The latter at once abandoned his excursion until he had secured attention for the injured boy.

Among his earliest professional engagements in this country was one as Associate Engineer with James P. Kirkwood, on the Norwich and Worcester Railroad. That line was constructed under their direction in 1835 and subsequently, and was probably the first road in this country on which a tunnel was built. His work for a few years following the completion of the Norwich line has not been ascertained, but in 1848 he was living in Boston, Mass. At that time he had an office at 23 Railroad Exchange as Consulting Engineer for railway location and surveys, dams, bridges and wharves. In July of that year he assisted in founding the Boston Society of Civil Engineers, the oldest existing engineering society in this country.

Very soon after this he became the Engineer of the Central Railroad of New Jersey, and made plans for the extension of the road from Whitehouse to Easton, in 1849. He remained Chief Engineer of this line for about three years.

In 1852 he had an office at 247 Broadway, New York. In the record of attendance at the meeting at which this Society was organized, his name is first. He was one of the leading spirits of the Society during its first two years, and held the office of President for fifteen years.

At the Annual Meeting of the Society, held November 6th, 1867, the following resolution was passed:

"*Resolved*, That we tender our thanks to Mr. James Laurie for his faithful services as our President, for his efforts to re-establish and reorganize this Society on a basis which gives promise of a successful and useful continuance, and particularly for his care of our funds, to which we are greatly indebted for our present unencumbered and hopeful condition."

* Memoir prepared from papers on file in the Library of the Society, and information furnished by J. W. Adams, W. E. Worthen, Walter Katté, C. H. Myers, Clemens Herschel and G. H. Bishop, Members Am. Soc. C. E., and Mr. Samuel Nott.

It is interesting to notice in this connection that the original constitutions of this Society and of the Boston Society of Civil Engineers are alike in many respects, which apparently indicates that Mr. Laurie's experience at the time of the founding of the Boston association proved useful to this Society during its organization.

In 1855 and 1856 he made a number of examinations of bridges in New York for the State authorities. In 1858 he was employed by the Province of Nova Scotia under a resolution requiring the employment of a competent engineer to report fully on the condition of the Nova Scotia Railway, the sum it should have cost and the expense of various extensions, besides matters relating to the operation of the lines. In 1859 and 1860 he was Engineer of this railway, and prepared plans for various extensions.

In 1862 he made elaborate surveys and a voluminous report on the Troy and Greenfield Railroad and the Hoosac Tunnel, and was retained as Consulting Engineer on this work by the State of Massachusetts for several years.

It was in 1862, also, while Chief Engineer of the New Haven, Hartford and Springfield Railroad, that he designed what is probably his greatest work, the bridge across the Connecticut River at Warehouse Point on the line of the New York, New Haven and Hartford Railroad. The iron work for this structure was bought in England, Mr. Laurie having gone there for the purpose and made a contract with William Fairbairn & Company of Manchester. It is a notable American example of riveted bridge work, one of its spans being 177.25 ft. long. Its many years of service cast no discredit upon its designer, when the increase in weight of rolling stock since 1862 is considered, and especially when it is understood that it is still in service on one of the main trunk lines of the country, while most bridges of the same age of a different form of structure have passed out of existence. The cost of the bridge, erected and completed, was 12.38 cents per pound in gold.

After the completion of this bridge in 1866 it is believed that Mr. Laurie spent his remaining days at Hartford. He was a bachelor and lived at the Allyn House. He was sometimes retained to report on various engineering works, among these engagements being an examination of the Lyman Viaduct on the Air Line Railroad about 1870, and an examination of the Eads Bridge at St. Louis for the bondholders, but as he had accumulated considerable property he lived practically in retirement until his death on March 16th, 1875. He had been ill for some time, and, though not confined to his room, was under the care of a physician.

He was buried in the Cedar Hill Cemetery at Hartford and a granite monument about 25 ft. high was erected on the spot. On one side of this monument there is a bronze likeness of Mr. Laurie, with

an inscription below ending: "By his talents and industry he gained the foremost rank in his profession."

His personal clerk and draftsman during the extension of the Central Railroad of New Jersey in 1850-52 was Walter Katté, M. Am. Soc. C. E., who pays the following tribute to his engineering ability:

"I have always felt the deepest respect and gratitude for the great benefit I derived from my experience, short as it was, under him. I learned a great many lessons at that time which have been of incalculable benefit to me since, especially in his exactitude of office methods and the sterling excellence of his designs in engineering practice. Had he lived in this epoch, instead of half a century earlier, he would have assuredly been found in the forefront of our present heaviest and most important engineering enterprises."

EDMUND FRENCH, M. Am. Soc. C. E.*

Died July 7th, 1860.

Edmund French, the fifteenth Member of the American Society of Civil Engineers, was a native of Connecticut, and, like many of his contemporaries engaged in railway engineering, received a military education.

He was graduated from the United States Military Academy at West Point as the seventh member of the class of 1828, being a classmate of Professor Albert E. Church, the eminent mathematician. He was assigned to the artillery branch, and in 1828-29 was on duty at the Artillery School at Ft. Monroe, Va. He was then assigned to topographical work and remained on this service until 1833, when he returned to Ft. Monroe. In 1833-34 he was stationed in Creek Nation, but returned to Ft. Monroe again in about a year, where he remained, except for a short stay at Ft. King, Fla., until his resignation from the service in May, 1836. At the time of his resignation he was a First Lieutenant of Artillery.

In civil engineering, he had a varied experience. In 1836-38 he was Assistant Engineer of the Croton Aqueduct of New York, and in 1838-47 Superintending Engineer of the Croton Dam and the Upper Section of the Croton Aqueduct. From 1847 to 1852 he was Resident Engineer of the Hudson River Railroad, and its General Superintendent in 1852-57. During 1852 he was also Superintendent of Machinery and Mechanical Engineer of this road. These duties did not occupy all his time, however, for he was General Superintendent of the Troy and

* Memoir prepared from information in "The Biographical Register of the Graduates of the United States Military Academy," by General G. W. Cullom.

Albany Railroad in 1851–57, Chief Engineer of the Newburgh, N. Y., Water-Works in 1852–57, and Chief Engineer of the Troy Union Railroad in 1852–57.

In 1857–59 he was Assistant Superintendent of the Treasury Building Extension at Washington, D. C.

He died on July 7th, 1860, aged 53 years, at Georgetown, D. C. He became a Member of the American Society of Civil Engineers on November 26th, 1852.

MARSHALL MARTAIN TIDD, M. Am. Soc. C. E.*

DIED AUGUST 20TH, 1895.

Marshall Martain Tidd was born in Woburn, Mass., August 1st, 1827. His early education was obtained in the public schools of Woburn. He lost the use of his right arm when a young child, owing to a fall upon the back of his head which resulted in the paralysis of the arm. Notwithstanding this, he was a very active and capable boy, and delighted in all kinds of out-of-door sports, such as swimming, sailing, canoeing, hunting, fishing, skating, etc., in all of which he excelled, notwithstanding the loss of his arm. He was expert in the use of tools and made many ingenious articles that required skilful work.

At the age of sixteen he went to work on the old Middlesex Canal, and for about two years attended one of the locks in Woburn.

He began his engineering experience as an assistant on the construction of the dam across the Merrimack River at Lawrence, Mass., under Charles S. Storrow, Hon. M. Am. Soc. C. E. This was before the days of photography, and one of Mr. Tidd's duties was to make freehand sketches showing the condition of the work at the end of each month. After the completion of the Lawrence dam he was occupied in drawing on wood and stone for illustrations of machines and mechanical devices. This business he followed for about 25 years, until the introduction of cheaper processes, and the increase in his more strictly civil engineering work caused him to abandon it. He displayed much ability in the use of pen, pencil and brush, his drawings being remarkable for their extreme accuracy and fineness of detail.

During these years he was connected with the construction of the Simpson patent wooden dry docks in East Boston, Mass., and Portland, Me., and was Consulting Engineer and Designer of the dry dock at the Erie Basin in Brooklyn, N. Y.

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* Memoir prepared by Henry Manley, Dexter Brackett and F. C. Coffin, Members Am. Soc. C. E.

In 1872 Mr. Tidd was elected Water Commissioner of his native town, the only public office he ever held. Although holding the office of Water Commissioner, he was also practically Engineer of the works, and his connection with these works led to his being engaged to design and superintend the construction of works of a similar character in other places, so that from this time to his death he devoted himself almost exclusively to questions relating to water supply and sewerage.

He designed and superintended the construction of works for the water supply of Natick, Lincoln, Hingham, Marlboro, Hudson, Weymouth, Hyde Park, Cohasset, Randolph, Holbrook, Vineyard Haven, Reading, and Fairhaven, Mass.; Lewiston, Gardiner, Richmond, Calais, Caribou, Dover, Foxcroft, Farmington and Madison, Me.; Hanover, N. H.; St. Stephen, N. B.; Charlottetown, Prince Edward Island; Yarmouth, N. S., and Ashland, Ky. In addition to the preceding he was employed to make improvements or additions to existing works in Fort Smith, Ark.; Tiffin, O.; Woonsocket, R. I.; Manchester and Nashua, N. H.; Bath, Brunswick, Waterville, Bangor, Bar Harbor, Me.; Medford, Melrose, Belmont, Maynard and Attleboro, Mass.

He was employed as an expert to report to capitalists upon the condition and value of many works in the West, also as an expert in cases of the taking of the works of private corporations by municipalities, at Syracuse, N.Y.; Auburn, Me.; Rochester, N.H.; Braintree, Haverhill and Quincy, Mass., and Milford, N. H.; as Consulting Engineer at Helena, Mont., and Phœnix, Ariz.; by the Maine Water Company, Cambridge, Mass., and others. He also designed and built the sewerage system at Marlboro, Mass. At the time of his death, he was employed upon the Bath Water-Works, Me.; the construction of the Woburn sewerage system, the plan of a sewerage system for Stoneham, Mass.; Bar Harbor, Me., Water-Works, and as Consulting Engineer on the Willimantic, Conn., Water-Works, and Cambridge, Mass., Water-Works; he was also retained as one of the board of arbitration in a suit for mill damages against the town of Attleboro, Mass.

As an engineer, Mr. Tidd's most striking traits were remarkable mechanical ability, keen observation, fertility of resource and entire and complete honesty of purpose.

He was very successful as an expert witness in legal controversies, he had a strong memory, was very careful in the collection of his data, and had a blunt, emphatic manner of stating his opinions which made him an excellent and convincing witness. As an expert engineer he had a very wide practice in the examination of proposed and existing works, and his familiarity with certain branches of mechanical engineering, acquired in the early days when a civil engineer was necessarily a mechanical engineer as well, resulted in his being retained frequently by mill owners.

To know a man completely it is necessary to know his recreations as well as his work. In earlier life Mr. Tidd's recreations were of the active out-of-door sort; later in life, perhaps his greatest interest was in horticulture and the care of his grounds. For a man of moderate means, he had a very fine collection of shrubs, his flowers, fruit trees and lawn were kept in the best of order and his grounds showed remarkable taste. He was a life member of the Massachusetts Horticultural Society, and was wonderfully well informed in all the details of raising fruit and flowers and the care of shrubbery. Another of his interests was his workshop, which was a model in its equipment of tools and their neat arrangement.

His other principal recreation was attendance upon the meetings and excursions of the several engineering societies of which he was an enthusiastic and liberal member.

In his relations with the members of his profession, he was liberal and generous, ever ready to impart freely to a brother engineer who came openly to him, from his knowledge, or the result of his experience.

He was married when about twenty-eight years of age to Abba S. Cole, who died in July, 1893. He had one daughter who survives him, as does also his aged mother.

He was a man of pronounced individuality, active and alert, both of mind and body, an excellent companion, clear-minded, frank, open and generous.

He became a Member of the American Society of Civil Engineers, October 2d, 1878. His death was occasioned by heart failure, the result of a severe attack of the grippe, about two years before.

CALEB GOLDSMITH FORSHEY, M. Am. Soc. C. E.*

Died July 25th, 1881.

Caleb Goldsmith Forshey was born on July 18th, 1812, in Somerset County, Pa. He was educated at Kenyon College, Gambier, O., and at the United States Military Academy at West Point, Grant and Sherman being cadets at the latter school at the same time.

After leaving West Point he resided in Natchez, Miss., where he became City Engineer, and was later, 1836–38, Professor of Mathematics

* Memoir prepared from information furnished by B. M. Harrod, G. A. Quinlan and William Starling, Members Am. Soc. C. E.

and Civil Engineering at Jefferson College, Washington, Miss. From 1847 to 1853 he resided in the town of Carrollton, now a part of New Orleans, and held the position of Town Surveyor. During 1852 and 1853 he was also connected with the United States Topographical Survey of the Mississippi Delta.

He left New Orleans in 1853 to open a military academy at Rutersville, Tex., which he conducted until 1861. When the civil war began, he entered the Confederate army, although previously opposed to secession, and rose to the rank of Lieutenant-Colonel of Engineers. He was in charge of the defences of Galveston at the time of the capture of that city. After the war was over, he held the position of Chief Engineer of the Galveston, Houston and Henderson Railroad until his return to New Orleans in 1872.

He then began his active work in connection with the improvements of the lower course of the Mississippi River, which occupied most of his attention until his death, and mainly established his reputation as an engineer. Records of his work are given in the "Report upon the Physics and Hydraulics of the Mississippi River" by Humphreys and Abbot, in the proceedings of the Levee Commission of 1874, and the reports of the Louisiana Levee Commission, of which he was a member. He was among the first observers to collect data relating to the physics of the Mississippi River, and was placed in charge of a hydrometrical party in the vicinity of New Orleans by Humphreys and Abbot.

He was one of the founders of the New Orleans Academy of Sciences, its first Vice-President, and chairman of the Sections of Meteorology and Civil Engineering. He presented several elaborate papers on the currents of the Mississippi to that organization and was among the first to draw attention to the possibility of improvements at the mouths of that river. He was an advocate of the St. Philip canal project and opposed the Eads jetty system.

Possessed of an iron constitution and determined will, he was untiring in his work and indefatigable in his desire to accomplish some good for the welfare of the public, often losing sight of his personal interests in so doing. With a mind prone to and trained in scientific methods, he was charitable in his opinions on everything honestly proposed, but merciless in his open contempt of all that was false or insincere. This last trait of his character militated against a wide personal popularity which his worth fully merited.

He was elected a Member of the American Society of Civil Engineers on August 7th, 1872, and contributed two papers to its *Transactions*, one entitled "The Levees of the Mississippi River," and the other "Cut-Offs on the Mississippi River." He died in New Orleans on July 25th, 1881.

JAMES HART RENO, M. Am. Soc. C. E.*

DIED AUGUST 5TH, 1881.

James Hart Reno began his professional career in 1866, when he was about nineteen years old, as Assistant Engineer in charge of the construction of about 8 miles of road on the Allegheny Valley Railway. Early in 1868 he left this position to become a transitman in a party on the Union Pacific Railway in Utah and Nevada. Early in the fall he was given a subdivision on construction in Nevada, which was abandoned later in the year and all the force brought to Utah. There he had charge of construction on the western side of the Promontory, and remained in the service of the company until late in June, 1869. For a few months in the latter part of that year he was Assistant Engineer on the location and construction of the Adirondack Company's roads, and he then entered the service of the Northern Pacific Railway Company. He remained about two years with this company, and had charge of the location and construction of about 93 miles of road. In May, 1872, he took charge of the survey and preliminary location of the line of the Texas and Pacific Railway from San Diego, Cal., to Pinos Villages, Ariz., a distance of 375 miles.

In May, 1873, Mr. Reno began another branch of engineering, as Assistant Engineer in charge of the street construction of the city of Pittsburg, Pa., which work was continued until January, 1877, when he was appointed County Engineer and Surveyor of Allegheny County, Pennsylvania, in charge of all the public structures of the county, including bridges and buildings.

He was elected a Member of the American Society of Civil Engineers, November 5th, 1879.

HENRIQUE HARRIS, M. Am. Soc. C. E.†

DIED OCTOBER 10TH, 1882.

Henrique Harris was born in 1837, and graduated from the Rensselaer Polytechnic Institute in 1861. He engaged in mercantile pursuits until 1870, when he entered the service of the Department of Public Works of Brooklyn, N. Y., in the capacity of District Engineer. He remained in this position until July, 1873, when he resigned to take charge of the public works in New Brunswick, N. J., under the Commissioners of Street and Sewers of that city. This position he held until the fall of 1878. On March 9th, 1879, he was appointed Chief Engineer of the New York and Manhattan Beach Railway, and held this position for some time. He died October 10th, 1882.

Mr. Harris was elected a member of the American Society of Civil Engineers, December 3d, 1873.

* Memoir prepared from papers on file at the House of the Society.
† Memoir prepared from papers on file at the House of the Society.

JAMES FREDERIC JOY, F. Am. Soc. C. E.*

Died September 24th, 1896.

James Frederic Joy was chiefly noted as the man who once probably, saved the State of Michigan from bankruptcy, although he was also prominent through his connection in important capacities with many of the great railway companies which developed the Central States with marvelous rapidity in the ten years immediately preceding the Civil War. Like many of the men who were conspicuous figures in the railway work of that period, Mr. Joy was a farmer's son. He was born December 20th, 1810, at Durham, N. H., and was brought up in the frugal, industrious manner characteristic of New England country life at the time.

He attended such schools as he could, and finally became himself a teacher in one of them. With the money earned in this way and a little assistance from his father, who was in not very good circumstances, he entered Dartmouth College. He graduated in 1833 and was selected to deliver the valedictory address. Modern languages, particularly French, and history were his favorite studies, and he retained his interest in them to the close of his life, one of his hobbies in later years being the collection of books relating to Washington and the Revolutionary War. From Dartmouth he went to Cambridge and entered the Harvard Law School, where Joseph Story took a particular interest in him. He had to leave Cambridge, however, in a short time and go back to teaching to earn enough money to carry him through the school. He became a preceptor in an academy at Pittsfield and also an instructor in Latin and Greek at Dartmouth College, and after a short time succeeded in laying by enough of his earnings to complete his legal studies.

The young lawyer then decided to hazard his fortunes in the "Northwest" of that time, and accordingly entered the law office of Senator Augustus S. Porter, of Detroit, in September, 1836. In the next year he was admitted to the Michigan bar and soon became a partner of George F. Porter. The firm were the legal advisers of the Bank of Michigan, at that time the only banking institution in the vicinity, and after its collapse Messrs. Joy and Porter were very busy in straightening out the affairs of the corporation. They were so successful in this work that a large and lucrative practice was soon built up, and when in 1847, the State was without funds and in a most embarrassed condition, Mr. Joy's standing was such that he was enabled to save its reputation.

* Memoir prepared in the office of the Society.

Michigan was at that time suffering from a plethora of public works, into the history of which it is unnecessary to enter here. Among these public works was the Michigan Central Railroad. This property was one which Mr. Joy considered to have considerable value, so he worked with John W. Brooks, a well-known railroad engineer, to induce eastern parties to buy it. The undertaking was successful, the credit of the State was made good, and the young lawyer was launched on his very successful railway career, which, strange to say, in view of the commanding position he won, was never particularly attractive to him, as his preference was for a general practice. The importance of this sale can be shown by quoting Mr. Joy's description of the conditions prevailing in 1846:

"A wave of wild speculation had swept over the country a few years before, which had resulted in almost universal bankruptcy. All the banks in the State had failed. The State itself was utterly bankrupt. It had issued State scrip to pay for work on its railroads until it had become practically worthless. The railroads were of strap rails laid on wooden stringers and well nigh worn out, and its construction could not be continued, nor could the State reconstruct it with heavier rails. The State was prostrate so far as its credit was concerned. There was no railroad through Canada. There was no railroad west of Kalamazoo."

The Michigan Central was rebuilt by its new owners and extended to Chicago. Then the Great Western Railroad was built in Canada, and afterward other lines were constructed which gave the system direct connections with most parts of the State.

When the Michigan Central negotiations were finished, Mr. Joy took an active part in the organization of the Chicago, Burlington and Quincy Railroad Company. He went over the route from Chicago to Burlington and Quincy, and, after becoming well acquainted with the country and its resources, he had little difficulty in financing the project. Then he became prominently connected with the extension of the road to Fort Kearney, Neb., and before long was in a commanding position among the railway operators of the country. He was elected President of the Michigan Central Railroad Company in 1865, and was largely instrumental in the construction of a number of lines, most of which ultimately passed into the control of the company of which he was the head. One of his most interesting enterprises was the first Detroit River tunnel, which was partly built, and another was the first canal at Sault Ste. Marie, which was turned over to the State as soon as it was completed.

Mr. Joy died on September 24th, 1896, leaving a daughter and three sons. He was elected a Fellow of the American Society of Civil Engineers on November 6th, 1872.

MARK TUCKER SEYMOUR, F. Am. Soc. C. E.*

Died May 30th, 1885.

Mark Tucker Seymour was born at Stillwater, Saratoga County, N. Y., on March 23d, 1820. He was a descendant of a family which was among the first to settle in that part of the country, and took a prominent part in public affairs at the time of the Revolution.

Mr. Seymour's early life was spent on a farm, his spare moments being given to study, particularly of matters relating to mechanics. His early engineering training was acquired as an apprentice to his eldest brother, who was a surveyor. He spent some time mapping the country in which he lived, and locating and constructing a number of railway lines in the western part of New York State. He afterwards made a specialty of bridge building, his first important contract being for the construction of all bridges on the Erie Railway, among them the original Portage Viaduct. He next undertook extensive contracts in Virginia, which were abandoned at the outbreak of the civil war. In 1869 he had a contract for building bridges on the Union Pacific Railway, including those at Dale Creek and Devil's Gate. He took similar contracts from the Chicago and South Western Road in 1870, the Canadian Southern in 1871, and the Massachusetts Central in 1881. An undertaking of a different character which he also contracted for was the Riverside Drive in New York City. The last ten years of his life were spent in New York, to which city he moved from Chicago where he lived for four years.

Mr. Seymour was elected a Fellow of the American Society of Civil Engineers, July 21st, 1870.

* Memoir prepared from information furnished by George S. Morison, Past-President Am. Soc. C. E., and from papers on file at the House of the Society.

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ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf, Thomas Rodd, A. E. Hunt.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—127 EAST TWENTY-THIRD STREET, NEW YORK.

Vol. XXIII. APRIL, 1897. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

April 7th, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William Rich Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 80 members and 9 guests.

The minutes of the meetings of March 3d and 17th, 1897, were approved as printed in *Proceedings* for March, 1897.

A paper by Andreas Lundteigen, Esq., entitled "Notes on Portland Cement Concrete," was presented by the Secretary, who read correspondence on the subject from Messrs. John F. Ward, Frederick H. Lewis, W. W. Maclay, Richard L. Humphrey, and W. E. Belknap. The paper was discussed by Messrs. R. W. Lesley, Henry Goldmark, George W. Tillson and James C. Meem.

Ballots were canvassed and the following candidates declared elected:

As Members.

Edward Austin Rix, San Francisco, Cal.
Charles Clifton Upham, New York City.
Jacobus Van der Hoek, Buffalo, N. Y.

As Associate Members.

Rudolph Philip Miller, New York City.
Charles Augustine Miner, Neptune, La.
Olaf Einar Mogensen, Pencoyd, Pa.
William Aaron Spalding, Waxahachie, Tex.
Harold Clair Stowe, Brooklyn, N. Y.
Albert Henry Zeller, St. Louis, Mo.

The Secretary announced the election by the Board of Direction on April 6th, 1897, of the following candidates:

Perley Egbert Stevens, Athens, Pa.
Robert Andrew Thompson, Lake Charles, La.
Benjamin Franklin Welton, New York City.

The ballot on the appointment of a committee to report on the proper manipulation of tests of cement was canvassed with the following result:

Number of ballots received	525
Number necessary to constitute a vote, in accordance with Article VI, Section 13, of the Constitution.....	521

Yeas, 507; nays, 18.

The Chair declared the vote carried in the affirmative.

Adjourned.

April 21st, 1897.—The meeting was called to order at 20.15 o'clock, Treasurer John Thomson in the chair; Charles Warren Hunt, Secretary, and present, also, 69 members and 14 guests.

A paper by Wynkoop Kiersted, M. Am. Soc. C. E., entitled "Valuation of Water-Works Property," was presented by the Secretary, together with correspondence on the subject from Messrs. Freeman C. Coffin, Edmund B. Weston, Peter Milne, D. C. Henny, H. F. Dunham, Arthur L. Adams, C. Palmer, Richard W. Sherman, Wm. G. Raymond, G. W. Pearsons, Foster Crowell and E. Kuichling. The paper was discussed by Messrs. C. E. Emery, Rudolph Hering, J. S. Haring, H. C. Meyer, John Thomson and L. L. Tribus.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

April 6th, 1897.—Nine members present.

The date for holding the Annual Convention was fixed as June 30th, 1897.

The membership of the Society was divided into seven geographical districts as required by the Constitution.*

Applications were considered and other routine business transacted.

Three candidates were elected as Juniors.

Adjourned.

ANNOUNCEMENTS.

ANNUAL CONVENTION.

The Annual Convention of 1897 will be held at Quebec, beginning Wednesday, June 30th. Arrangements of the details of the meeting are not yet completed, but will be announced in a short time.

SEVENTH INTERNATIONAL CONGRESS ON INTERNAL NAVIGATION.

President J. F. W. Conrad of the Permanent Commission of the International Congress of Internal Navigation desires to announce to this Society that the Seventh Congress will be convened at Brussels, Belgium, in August, 1898.

NOMINATING COMMITTEE.

Under Article VII, Section 1, of the Constitution, the Board of Direction has divided the territory occupied by the membership into seven geographical districts, for the purposes of the Nominating Committee:

District No. 1.—The territory within 50 miles of the Post Office in the city of New York.

District No. 2.—The remainder of the States of New York and New Jersey, and Canada.

District No. 3.—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and the remainder of Connecticut, and all foreign countries.

District No. 4.—Pennsylvania, Delaware, Maryland and District of Columbia.

District No. 5.—Michigan, Ohio, Indiana, Illinois and Wisconsin.

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* See Announcements.

District No. 6.—Minnesota, Iowa, Missouri, Kansas, Nebraska, North Dakota, South Dakota, Washington, Montana, Wyoming, Idaho, Colorado, Utah, Oregon and Nevada.

District No. 7.—Virginia, West Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Florida, Texas, Tennessee, Kentucky, Indian Territory, Oklahoma, New Mexico, Arizona, Arkansas and California.

MEETINGS.

Wednesday, May 5th, 1897, at 20 o'clock, a regular meeting will be held at which a paper by George W. Tillson, M. Am. Soc. C. E., entitled "Asphalt and Asphalt Pavements" will be presented. It is printed in this number of *Proceedings.*

Wednesday, May 19th, 1897, at 20 o'clock, a regular meeting will be held at which a paper by E. Kuichling, M. Am. Soc. C. E., entitled "The Financial Management of Water-Works" will be presented. It is printed in this number of *Proceedings.*

DISCUSSIONS.

Discussion on the paper by Eugene R. Smith, Jun. Am. Soc. C. E., entitled "The Compressibility of Salt Marsh Under the Weight of Earth Fill," which was presented at the meeting of March 17th, will be closed May 1st, 1897.

Discussion on the paper by Andreas Lundteigen, Esq., entitled "Notes on Portland Cement Concrete," which was presented at the meeting of April 7th, will be closed May 15th, 1897.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Membership.
UPHAM, CHARLES CLIFTON	Consulting Eng., 2 Cortlandt St., New York City	April 7, 1897
VAN DER HOEK, JACOBUS	Div. Eng. Lehigh Valley R. R., 127 Puffer St., Buffalo, N. Y.	April 7, 1897

ASSOCIATE MEMBERS.

ABELLA, JUAN	691 Calle Bolivar, Buenos Aires, Argentine Republic	Jan. 6, 1897
GREENE, CARLETON	Supt. of Machinery, Barber Asphalt Paving Co., 178 Walden Ave., Buffalo, N. Y.	Mar. 3, 1897
MOGENSEN, OLAF EINAR	Care Pencoyd Iron Works, Pencoyd, Pa	April 7, 1897
ZELLER, ALBERT HENRY	Board of Public Improvements, City Hall, St. Louis, Mo.	April 7, 1897

JUNIORS.

ELLIS, GEORGE EZRA	(Inspector of Signals, Spuyten Duyvil, Hudson Div., N. Y. C. & H. R. R. R.), 35 Pier St., Yonkers, N. Y.	Mar. 2, 1897
FORD, ROBERT HENRY	Civil Engineer, Central Vermont R. R., St. Albans, Vt.	Mar. 2, 1897
REYNOLDS, JUSTIN OAKLEY	28 West 61st St., New York City	Oct. 6, 1896
WALSH, GEORGE SCHERZER	Care of A. J. Scherzer, Santa Ana, Salvador, C. A.	Mar. 2, 1897
WELTON, BENJAMIN FRANKLIN	New Dorp, Staten Island, N. Y.	April 6, 1897

CHANGES AND CORRECTIONS.

MEMBERS.

ABBOT, FREDERIC VAUGHAN	Capt. Corps of Engrs., U. S. A., U. S. Engr.'s Office, Custom House, Charleston, S. C.
BALDWIN, FRED HIXON	150 Sixth Ave., Brooklyn, N. Y.
BARLOW, JOHN QUINCY	Prin. Asst. Engr., Gold Creek Nevada Mining Co., Gold Creek, Nev.

BLACK, WILLIAM MURRAY.............Capt. Corps of Engrs., U. S. A., Engineer Commissioner, D. C., Office District Commissioners, Washington, D. C.
BRECKENRIDGE, CABELL..............Danville, Ky.
COE, WILLIAM WATSON...............American Surety Co., 100 Broadway, New York City.
DAVIS, FRANK PAUL.................American Electric & Mfg. Co., Caracas, Venezuela, S. A.
HARRINGTON, EPHRAIM...............60 State St., Room 810, Boston, Mass.
HODGE, HENRY WILSON...............27 Pine St., New York City.
HUTCHINSON, GEORGE HUNT..........1607 Bluff St., Pittsburg, Pa.
LUDLOW, WILLIAM...................Lt.-Col. Corps of Engrs., U. S. A., Army Bldg., Whitehall St., New York City.
McCOLLOM, THOMAS CHALMERS........4606 Springfield Ave., Philadelphia, Pa.
NOURSE, EDWIN GREEN...............302 East Broadway, Winona, Minn.
PLIMPTON, ARTHUR LESLIE...........Chf. Engr., Civ. Engr. Dept., West End St. Ry., 439 Albany St., Boston, Mass.
PORTER, ALBERT HEZEKIAH...........403 The Osborn, Cleveland, Ohio.
POWELL, CHARLES FRANCIS...........Maj., Corps of Engrs., U. S. A., U. S. Engr.'s Office, Pittsburg, Pa.
TAYLOR, NORTON LONGSTRETH.........Care of Chas. S. Bihler, Div. Engr., N. P. Headquarters Bldg., Tacoma, Wash.
TOWLE, STEVENSON..................Cons. Engr. Dept., Public Works, 150 Nassau St., New York City.
TROTTER, ALFRED WILLIAMS..........26 Cortlandt St., New York City.
WILSON, JOHN MOULDER..............Brig.-Gen., Chief of Engrs., U. S. A., War Dept., Washington, D. C.
WROTNOWSKI, ARTHUR F..............Paseo de la Reforma No. 108, Mexico City, Mexico.

ASSOCIATE MEMBERS.

HOUSTON, JOHN JAY LAFAYETTE. .....2720 N. Lincoln St., Sta. X, Chicago, Ill.
JACOB, ALFRED PETER...............Engr. of Const. Board of Education, 585 Broadway, New York City.
MATHEWSON, ISAAC..................Ciudad Juarez, Mexico.
MILLER, HEW......................Shore Road, near 70th St., South Brooklyn, N. Y.
MILLER, SHREWSBURY BEAUREGARD ...Woodstock, Ulster Co., N. Y.
WILCOX, FRED ELMER ....70 Waring Place, Yonkers, N. Y.

ASSOCIATES.

HARRISON, LOUIS BALDWIN ....Waverly Bldg., Hartford, Conn.
LINDENBERGER, CASSIUS HOWARD .....Draftsman, Johnson Company, Johnstown, Pa.
TOMKINS, CALVIN ....120 Liberty St., New York City.

JUNIORS.

Baehr, William Alfred	561 B 28th St., Milwaukee, Wis.
Braxton, Jaquelin Marshall	Fredericksburg, Va.
Bell, Gilbert James	Care of A. T. & S. F. R. R., Joliet, Ill.
Cogswell, Jr., Charles Perkins	Div. Engr.'s Office, N. Y., N. H. & H. R. R., Providence, R. I.
Davis, Joseph Baker	51 So. Ingalls St., Ann Arbor, Mich.
Ford, William Hayden	Hanover, N. H.
Gregory, Charles Emerson	135 West 117th St., New York City.
Jackson, William	Hotel Columbus, Harrisburg, Pa.
Sirrine, Joseph Emory	435 W. McBee Ave., Greenville, S. C.
Smith, Walter Tenny	478 S. 43d Ave., Chicago, Ill.
Smyth, Arthur Moult	20 Fishers Lane, Germantown, Philadelphia, Pa.
Van Zile, Harry Lee	120 Liberty St., New York City.
Wallace, William McGehee	616 Eighteenth St., N. W., Washington, D. C.

FELLOW.

Gurnee, Walter S	80 Broadway, New York City.

DEATHS.

Fink, Albert	Elected Member July 20th, 1870; President November 5th, 1879, to November 3d, 1880; died April 3d, 1897.
Worthen, William Ezra	Elected Member December 4th, 1867; Hon. Member April 4th, 1893; President January 19th, 1887, to January 18th, 1888; died April 2d, 1897.

RESIGNED.

Horatio Seymour	Resignation accepted April 6th, 1897.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Alabama Industrial and Scientific Society, University, Ala.:
Proceedings, Vol. vi, Part 2, 1896.

From Alumni Association of the Albany Medical College, Albany, N. Y.:
Albany Medical Annals, March and April, 1897. Special Double Number containing "The Relation of Impure Water to Disease."

From American Institute of Mining Engineers, New York, N. Y.:
Action of Blast Furnace Gases upon Various Iron Ores.
A Decimal Gauge for Wire and Sheet Iron.
Biographical Notices of Gabriel Auguste Daubrée, J. F. Holloway, Alexander Trippel and Joseph D. Weeks.
Concentration of Ores in the Butte District, Montana.
Current Theories of the Hardening of Steel.
Electricity in Mining.
Proceedings of the Seventy-second Meeting, Chicago, Ill., February, 1897.
Some Mines of Rosita and Silver Cliff, Colorado.
Sulphur in Embreeville Pig Iron.
The Calorific Value of Certain Coals as Determined by the Mahler Calorimeter.
The Development of Colorado's Mining Industry.
The Distribution of the Precious Metals and Impurities in Copper, and Suggestions for a Rational Mode of Sampling.
The Geology of the Magnetites near Fort Henry, N. Y., and especially those of Mineville.
The Hand Auger and Hand Drill in Prospecting Work.
The Manganese Deposits of the Department of Panama, Republic of Colombia.
The Microstructure of Steel and the Current Theories of Hardening.
The Occurrence and Behavior of Tellurium in Gold Ores, more particularly with reference to the Potsdam Ores of the Black Hills, South Dakota.
The Occurrence and Treatment of Certain Gold Ores of Park County, Colorado.
The Precipitation of Gold by Zinc-Thread from Dilute and Foul Cyanide-Solutions.
The Physics of Cast Iron.
The Spitzkasten and Settling Tank.
Vein-Walls.

From Horace Andrews, Albany, N. Y.:
Annual Report of the City Engineer of Albany, N. Y., for the year ending January 1, 1897.

From George Joseph Bell, Carlisle, Eng.:
A Practical Treatise on Segmental and Elliptical Oblique or Skew Arches.

From Board of Water Commissioners, St. Paul, Minn.:
Fifteenth Annual Report, January 1, 1897.

From California Academy of Sciences, San Francisco, Cal.:
Proceedings, Vol. VI, 1896.
The Geology of Santa Catalina Island.

From Canadian Society of Civil Engineers, Montreal, Can.:
Charter, By-Laws and List of Members, 1897.

From F. W. Cappelen, Minneapolis, Minn.:
Annual Report of the City Engineer of the City of Minneapolis, for the year ending December 31, 1896.

From Connecticut State Board of Health, New Haven, Conn.:
Nineteenth Annual Report, for the year ending December 31, 1895.

From David T. Day, Washington, D. C.;
The Production of Cement in 1895.

From Engineers' Club, New York, N. Y.:
Constitution, Rules, Officers and Members, 1897.

From Clemens Herschel, New York, N. Y.:
One Hundred and Fifteen Experiments on the Carrying Capacity of Large, Riveted, Metal Conduits up to Six Feet per Second of Velocity of Flow.

From Edwin A. Hill, Washington, D. C.:
Rules of Practice in the United States Patent Office, in Force February 9th, 1897.

From Institute of Marine Engineers, Stratford, Eng.:
Discussion on Engineers of the Royal Naval Reserve.
Discussion on the Qualifications Necessary for Marine Engineers.

From P. H. Jackson & Co., San Francisco, Cal.:
Improvement in Building Construction, mainly relating to Portland Cement Concrete and Artificial Stone, combined with Iron and Steel.

From J. B. Johnson, St. Louis, Mo.:
The Materials of Construction—A Treatise for Engineers on the Strength of Engineering Materials.

From Kansas University, Lawrence, Kan.:
The Kansas University Quarterly, Vol. vi, No. 1.

From Library Bureau, New York, N. Y.:
Classified Illustrated Catalogue.

From Massachusetts Institute of Technology, Boston, Mass.:
Annual Report of the President and Treasurer, December 9th, 1896.
Annual Catalogue, 1896–1897.

From Mining Department, Pretoria, S.A.R.:
Vergelijkende Staat van de Opbrengst der Publieke Delverijen over de Jaren 1895 en 1896.

From Mississippi River Commission, St. Louis, Mo.:
Stages of the Mississippi River and of its Principal Tributaries for 1896.

From North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, Eng.:
Transactions, Vol. XLV, Parts 4, 5; XLVI, Parts 1-2.
Annual Report of the Council, 1895-1896, and List of Members, 1896-97.

From Ohio State University, Columbus, Ohio:
Catalogue, 1896-1897.

From Patent Office, London, Eng.:
Abridgments of Specifications of Patents for Inventions. Lifting, Hauling and Loading; Pumps and other Means for Raising and Forcing Liquids; Hand Tools and Benches for the Use of Metal, Wood and Stone Workers; Furniture and Upholstery; Mining, Quarrying, Tunneling and Well-Sinking; Mechanism and Mill Gearing; Furnaces and Kilns; Hollow-Ware. Reports of Patent, Design and Trade-Mark Cases, Vol. XIV, Nos. 1 to 8.

From Pennsylvania Railroad Company, Philadelphia, Pa.:
Fiftieth Anniversary of the Incorporation of the Pennsylvania Railroad Company, April 13th, 1896.
Fiftieth Annual Report for the year 1896.

From Public Works Department, Madras Presidency, India:
Administration Report of the Irrigation Branch for the year 1895-96.

From Railroad Commissioners of Massachusetts, Boston, Mass.:
Twenty-eighth Annual Report, January, 1897.

From Baron Quinette de Rochemont, Paris, France.:
Cours de Travaux Maritimes.

From Royal Technical Highschool, Berlin, Germany.:
Ueber innere Anschauung und bildliches Denken. Rede zum Geburtsfeste seiner Majestät des Kaisers und Königs Wilhelm II, 26 Januar, 1897.

From Hamilton Smith, Jr., London, Eng.:
Superintendent's Report of the Alaska Mexican Gold Mining Company for the year ending December 31, 1896.

From Society of Civil Engineers of France, Paris, France:
Congres de 1896.
Annuaire de 1897.

From Society of Naval Architects and Marine Engineers, New York, N. Y.:
Transactions. Vol. IV, 1896.

From H. A. Sumner, Denver, Colo.:
Eighth Biennial Report of the State Engineer of Colorado for the years 1895 and 1896.

From U. S. Coast and Geodetic Survey:
Report of the Superintendent showing the Progress of the Work during the fiscal year ending with June, 1895.

From U. S. Department of Agriculture, Weather Bureau:
Bulletins Nos. 12, 13, 14, 15, 16, 18, 19 and 20: Report on the Condensation of Atmospheric Moisture; Temperatures Injurious to Food Products in Storage and during Transportation and Methods of Protection from the Same; Report of the Third and Fourth Annual Meetings of the American Association of State Weather Service; Protection from Lightning; The Determination of the Relative Quantities of Aqueous Vapor in the Atmosphere by Means of the Absorption Lines of the Spectrum; Report on the Relative Humidity of Southern New England and other Localities; Storms, Storm Tracks and Weather Forecasting.
Report of the Chief of the Weather Bureau, 1895-96.
Monthly Weather Review, Annual Summary for 1896.

From U. S. Department of State:
Special Consular Reports, Money and Prices in Foreign Countries. Vol. XIII, Part 2.

From U. S. Geological Survey:
Magnetic Declination in the United States.

From U. S. Treasury Department:
The Foreign Commerce and Navigation of the United States for the year ending June 30th, 1896, Vol. II.

From U. S. War Department, Chief of Engineers:
Twenty-five Reports on the Improvement of Certain Rivers and Harbors.
Forty-one Specifications for the Improvement of Certain Rivers and Harbors.

From University of the State of New York, Albany, N. Y.:
Eleventh Annual Report of the State Board of Health of New York, 1891. 2 vols.
Annual Reports of the Auditor of the Canal Department (New York) of the Tolls, Trade and Tonnage of the Canals for 1869, 1871, 1876, 1878 and 1879.
Annual Financial Reports of the Auditor of the Canal Department for 1866, 1869, 1871, 1872, 1875, 1876 and 1877.
Annual Report of the State Engineer and Surveyor on the Canals of New York for the year 1860.
Examination Department. Third Annual Report, 1895.

From Water Commissioners, Albany, N. Y.:
Forty-sixth Annual Report of the Water Commissioners of the City of Albany for the year ending December 31st, 1896; also a Report recommending that the Water Supply be Filtered by the Slow Sand Filtration Method.

From Worcester Polytechnic Institute, Worcester, Mass.:
Twenty-seventh Annual Catalogue, 1897.

From E. A. Ziffer, Vienna, Aus.:
Note sur le IXe. Assemblée Générale de l'Union Internationale Permanente de Tramways, tenue à Stockholm du 26 au 29 Août, 1896.

BOOK NOTICES.

A Practical Treatise on Segmental and Elliptical Oblique or Skew Arches, Setting Forth the Principles and Details of Construction in Clear and Simple Terms. By George Joseph Bell, County Surveyor and Bridge Master of Cumberland. New York, Spon & Chamberlain. Cloth, $10\frac{1}{2} \times 7\frac{1}{2}$ ins., pp. 125, eight folding plates.

The scope of this volume is stated in the preface as follows: The author's object has been "to place in the hands of engineers, architects, builders, contractors and especially working masons, in a tabulated form, the results of his calculations for 72 oblique bridges, designed to suit almost any situation, in spans ranging from 10 to 50 ft. advancing by 5 ft., and from 35° to 70° advancing by 5°, also decimal multipliers for finding the corresponding dimensions for any span in the same degree of obliquity, thus saving much valuable time to all those engaged in practical constructions of this kind. Every theoretic and adjusted dimension necessary for enabling the draftsman to make his projection, and thus get his templates for drawing the plan, elevation and section, or for building the bridge from certain specified dimensions, is given in the tables of this essay.

"An example in projection is given to show the mode of producing the templates for making the drawings of an oblique bridge, also the mode of obtaining the templates for the intradosal and extradosal angles correctly, the twisting rules, and all other templates necessary for carrying out and completing the work. Plans, elevations and sections of oblique bridges are given with a specification, form of tender, agreement and bond; also an example of a skew gusset or V-shaped piece of masonry, built obliquely against an old bridge to illustrate an inexpensive method of doing away with all dangerous corners at the ends of existing bridges."

Experiments upon the Contraction of the Liquid Vein Issuing from an Orifice, and upon the Distribution of the Velocities within it. By H. Bazin, Inspecteur Général des Ponts et Chaussées. Translated from Mémoires présentés par divars Savants à l'Académie des Sciences de l'Institut de France, Tome xxxii. By John C. Trautwine, Civil Engineer. New York, John Wiley & Sons. Cloth, 9 x 6 ins., pp. 64, 1 folding plate.

The nature of M. Bazin's memoir is indicated by the following extract from a report of a committee of the Academy of Sciences of the French Institute. "Notwithstanding the numerous experiments made since the seventeenth century upon the flow of liquid veins through orifices, there are important matters connected with this phenomenon which still remain undetermined, or so imperfectly known as to give rise to most inexact hypotheses. Until now we have had no experimental results respecting the pressures exerted in the interior of the vein, or upon the velocities of the separate filaments. It is therefore highly desirable that delicate observations upon a large scale should be undertaken for the measurement of the pressures and velocities within the issuing vein under considerable heads, and with both vertical and horizontal orifices of diverse forms. M. Bazin's memoir contains an account of a large number of just such observations, made at Dijon since 1890, and concluded within the last few months. The memoir contains an elaborate study of the flow through a vertical rectangular orifice, of the same width as the reservoir itself, and furnished externally with two flat cheek-pieces for preventing the lateral dilation of the vein. These are, so far as we know, the first precise observations made in such a case, the most important of all from a theoretical point of view, since it is the most elementary, and that to which mathematical analysis can be the most completely applied." Mr. Trautwine's translation was read by M. Bazin, and its publication was authorized by him.

1897. APRIL. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

CONTENTS:

ASPHALT AND ASPHALT PAVEMENTS.

By GEORGE W. TILLSON, M. Am. Soc. C. E.

TO BE PRESENTED MAY 5TH, 1897.

Asphalt.—The bitumen which forms the base of asphalt is defined by Professor S. F. Peckham as "that large class of substances occurring in Nature as minerals and consisting chiefly of mixtures of compounds of carbon and hydrogen, with nitrogen, sulphur and oxygen as more rare constituents." In this paper bitumen will be considered as any natural hydro-carbon soluble in carbon bisulphide, and any substance containing hard bitumen will be called asphalt. Of the bitumen itself, the portion soluble in ether is called petrolene, and the remainder soluble in chloroform or carbon bisulphide asphaltene. For an asphalt suitable for paving, the bitumen should contain not more than 25% or 30% of asphaltene.

The amount of bitumen in asphalt is not so important as regards final results, but its relative quantity influences the commercial value of the asphalt in consequence of the cost of handling and refining

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meetings, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

it, and particularly in consequence of the effect it has on the number of yards of pavement that can be laid per ton of crude material.

This bitumen is of varying quality, and upon its character depends the value of the asphalt for paving purposes. The petrolene gives the cementing property to the asphalt, while the asphaltene forms the body of the material. If an asphalt contains too much petrolene, it is soft and sticky and makes a sticky pavement. If the asphaltene be in excess, the pavement will be hard and liable to crack and disintegrate. The petrolene is the solvent for the asphaltene and must be added to a hard asphalt in such quantities as will give an asphaltic cement of proper viscosity. Upon the preparation of this asphaltic cement depends the success of the completed pavement.

According to Boussingault the formula for petrolene is $C_{20}\,H_{32}$, and for asphaltene $C_{20}\,H_{32}\,O_{31}$; that is, the petrolene has become oxidized. Thomson deduces the following formulas: petrolene, $C_{10}\,H_8$; asphaltene, $C_{20}\,H_{16}\,O_3$. These two substances, it should be said, have not been clearly determined by chemists, whose results vary greatly.

The opinions of Dr. H. Endemann* would seem to overturn the generally accepted theories as regards the nature of asphaltene and petrolene. He adopts a different method of analysis and arrives at very different results. In speaking of the present methods in use in America, he says:

"I had to admit and do admit that the analysis as carried out by the later methods suffices to make identity or non-identity of two samples probable or highly probable. It is also adapted to watch the supply of a single mine or the refining of asphalt from the same source; but it does not admit of basing any conclusions upon the results, if we work on asphalts from different sources."

He proceeds to demonstrate by an analysis of refined Mexican and Trinidad asphalt, using the two processes, that the product which has generally been called petrolene contains only about 43% of petrolene proper, the reason being that when asphalt is treated with petroleum ether, not only the petrolene is dissolved, but also a large amount of asphaltene. By these analyses he deduces the following results:

	Petrolene.	Asphaltene.
Trinidad Lake..........	13.70 per cent.	46.28 per cent.
Trinidad Land..........	10.74 "	47.70 "
Mexican................	37.45 "	59.85 "

*See an article entitled "An Analysis of Asphalt" in the *Journal* of the Society of Chemical Industry, Vol. xv, No. 12.

and adds:

"I believe no one accustomed to the figures generally reported for these three excellent asphalts would recognize them in this shape." By a further analysis he deduces for asphaltene the formula $C_{13} H_{18} O$ or a multiple, and for petrolene $C_n H_{2n}$, adding:

"While the formula for asphaltene is verified by direct analyses, that of petrolene is deduced from a mixture, and may require verification. Petrolene also includes a series of compounds, while asphaltene appears as a single body. It differs from the substance called asphaltene by Boussingault by containing less oxygen."

He gives the following as a result of an analysis of refined Mexican asphalt by the old method and the one proposed by himself:

	Old Method.	Proposed Method.
Petrolene	87.12 per cent.	26.51 per cent.
Asphaltene	10.19 "	70.80 "
Inorganic	0.27 "	0.27 "
Organic, not bituminous	2.42 "	2.42 "
	100.00	100.00

He further says:

"I have been asked whether it would not be possible to recalculate the many analyses of especially crude asphalts made during the last few years to avoid the loss of so much labor. To this I have to answer that it is not possible for the reason that the higher petrolenes, when dissolved in petroleum ether, exert a greater dissolving influence upon asphaltene than the lower.

"However, as regards refined paving asphalts an approximation is possible, and may be reached by dividing the petrolene found according to old-style analysis by $3\frac{1}{3}$. This will give us real petrolene. The difference between this figure and the original is to be added to the asphaltene."

This controversy must be left for American chemists to settle, for when doctors disagree, the layman should remain quiet and await results. It is not proposed in this paper to discuss asphalt in all its forms, but only in those that are used for pavements. The engineer must leave the patient investigation of these materials to chemists and accept their conclusions.

The principal places where asphalt is found are the Pitch Lake on the island of Trinidad; Bermudez, Venezuela; Seyssel, France; Travers, Switzerland; Ragusa, Sicily; and in California and Utah, U. S. Some deposits have also been found in Mexico, Kentucky, Texas, Montana, Colorado and Indian Territory.

Trinidad Asphalt.—At the time of the author's visit to Trinidad the asphalt was being dug from the lake and carted to the shore with mules. It was then loaded into lighters and taken to the ships anchored in the offing. Since then, however, the concessionaires have constructed a railroad from the shore to and around the lake, so that the pitch can be loaded upon the cars, drawn to the shore, out on an iron pier, and then dumped direct into the hold of the waiting ship, thus greatly reducing the expense of loading.

The material is easily dug up by negro laborers with ordinary pickaxes in chunks averaging about one-half a cubic foot each, the excavations being made of perhaps 5 or 6 ft., or of any convenient depth.

These excavations will fill up from the pressure below in about 48 hours. The surface of the lake has been compared to one formed by placing together a number of large mushrooms, the water previously spoken of standing in the depressions where the mushrooms come together. It has been thought by geologists that this appearance was caused by the material being forced up in a liquid form through a large number of orifices. These different streams, coming together at the top, form a surface, which, when hardened, presents the appearance described.

The asphalt is brought to this country generally in its crude state, and is refined at various points where most convenient for distribution. This refining process consists of heating the material in large iron retorts to a temperature of about 400° Fahr. for five or six days. This serves to evaporate all the water, and drives off all the volatile oils. The solid foreign matter is allowed to settle to the bottom, and the remainder is drawn off into barrels for shipment. The sediment is then taken out, and is used for sidewalks or similar purposes. Three tons of the crude material makes about 2 tons of the refined.

Another process of refining or drying asphalt has been used more recently. The apparatus consists of an iron tank large enough to contain about 30 tons of the material. In this tank is a continuous pipe arranged in gangs, something similar to a steam radiator, having a steam pipe to take the condensed water back to the boiler. Another set of pipes, called the live-steam pipes, has a direct boiler connection and a number of jets inserted in it at the bottom, so that the material in the tank can be kept in constant agitation by the injection

of hot steam through these jets, thus ensuring a complete and even mixture, as well as more rapid evaporation. After the tank is filled with asphalt, steam is applied at a pressure sufficient to produce a heat of about 300° Fahr. The application of this heat for fifteen or sixteen hours is sufficient in most cases to evaporate all the water from the asphalt, when it is drawn off into barrels for shipment. If the material is to be used near the refining plant, the flux is added before the product is drawn off and the asphaltic cement made on the spot. This method is generally called the drying process, and is economical, both in time and material, as it only requires sixteen hours against ninety by the old, and there is no wastage of material. It is held that as so large an amount of extraneous matter must be added to make the pavement, it is a waste of material to lose the amount of sediment which is very similar to what is afterwards added, and under the old plan was often a total loss. This system has been in operation about two years.

An analysis of the refined lake product gave the following result: bitumen, 55.6%; foreign matter, 44.4%; petrolene, 70.12%; asphaltene, 29.78%; specific gravity, 1.38.

California Asphalt.—California produces nearly all the United States asphalt used for paving purposes. While it can be found in this state in nearly all its stages of development, but three of these are adapted to pavements, namely, the maltha, hard asphalt and bituminous rock.

Maltha is a liquid asphalt used principally as a flux for the harder material. It contains a large percentage of bitumen, of which nearly all is petrolene; this determines its value as a flux. On account of the inconvenience of shipping it in its natural condition, the asphaltic cement is made near the mines, which are in Santa Barbara County near the city of the same name. The sand and vast beds of underlying shale in this vicinity are saturated with the material, but at present the maltha is obtained from the sand. An upper surface of about 1 ft. of soil is washed off into the ocean and the bed of sand left full and clean. This sand is then gathered up and the maltha extracted by a patent mechanical process. This bed probably extends for several miles under the sea, as the water for a long distance up and down the coast is covered with an oily film showing that this same material must be forced up from the bottom of the ocean. The composition

of this material when ready for use is 98.26% bitumen and 1.74% mineral matter; the petrolene amounts to 92.5 per cent. The specific gravity is 1.05.

Some 25 miles east of this deposit is located the principal deposit of the hard asphalt, which extends over an area of several hundred acres. This material is quite hard, presenting an appearance somewhat similar to refined Trinidad. When refined it is treated in practically the same manner as that before described, but the paving cement is often made by mixing the crude material and the maltha at a low temperature for only a few hours, the proportions of the mixture depending upon the consistency of the cement required. The composition of the natural product is: bitumen, 59.15%; organic matter, 1.10%; mineral matter, 39.75%; petrolene, 42.50%; specific gravity, 1.25.

Another deposit of hard asphalt has been found in Kern County of probably the same origin, but containing a larger percentage of bitumen. It is treated, both in refining and fluxing, in the same manner as that from the Santa Barbara mines. The refined product contains: bitumen, 93.27%; mineral matter, 5.77%; organic matter, 0.54%; moisture, 0.42%; petrolene, 71.27%; asphaltene, 28.73 per cent.

In Santa Cruz, San Luis Obispo and Monterey Counties are found deposits of asphalt of an entirely different nature, and pavements laid with its product must not be confounded with the others. It consists of sand thoroughly mixed with an asphalt of such a nature as to make a good pavement in a natural state. The sand is of all grades of fineness, sometimes largely mixed with clay, and often so hard as to be almost a sandstone. Pavements of this material have been quite extensively laid in California cities, the method being simply to heat the crude product so that it can be rolled to a hard smooth surface on the street, in some cases without any prepared foundation. It is not strange that the result of such operations should often prove failures, as no special care seems to have been taken to select the best of the material at hand. These failures have sometimes been charged improperly to the other California asphalts.

Bermudez Asphalt. The deposit of Bermudez asphalt is situated in the state of the same name in Venezuela. It is across the Gulf of Paria from the Island of Trinidad, and some people think the two

deposits are connected subterraneously. The lake is about 5 miles from the shipping point, which itself is 25 miles up a river from the Gulf. It includes an area of some 1 200 or 1 500 acres, covered generally with quite a heavy growth of grass and bushes. Through the lake runs a so-called stream of liquid asphalt, varying in width from 100 to 400 ft. With the exception of this stream, a person can easily walk over the entire surface of the lake, but upon the stream itself it is not safe to venture after the sun is two or three hours high. A portable railroad is built out into the lake, upon which light hand-cars are run. After being loaded, the cars are pushed to the shore, where they are unloaded into other cars, and the material then hauled to the shipping point over a permanent steam railroad. These cars are provided with boxes containing about a ton of the crude material, and when delivered alongside the vessel at the wharf, the boxes are hoisted from the cars and lowered into the hold of the vessel and there dumped.

The first pavement of Bermudez asphalt was laid in Detroit in 1892. When refined, the asphalt is composed of: bitumen, 97.22%; mineral matter, 1.50%; organic matter, 1.28%; petrolene, 77.90%; asphaltene, 22.10%; specific gravity, 1.08.

Utah Asphalt.—The deposits in Utah are situated in Utah County. They consist of a vein of limestone about 8 ft. in thickness, but only one-fourth of this contains sufficient bitumen to make it profitable for use, the amount being about 30 per cent. In eastern Utah is another deposit called gum asphalt, which is claimed to be pure bitumen. An analysis shows: carbon, 81%; hydrogen, 10%; nitrogen, 3%; and oxygen, 6 per cent.

In preparing a mixture for street work the gum asphalt is melted and fluxed with a small amount of residuum. It is then mixed in the proper proportions with hot sand and the bituminous limestone. This mixing is done in cylinders surrounded with steam jackets, in which steam at a temperature of 600° Fahr. is kept during the mixing, which continues a few minutes, when the mass is dumped into carts and taken to the street. Pavements of this material have been laid in Salt Lake City, Minneapolis, and Marion, O.

Kentucky Asphalt.—The Kentucky deposits are found in sandstone, and should be classed as the rock asphalts. The output is not large, and very little information could be obtained concerning it. Some years ago two pieces of pavement were laid with this material in Brooklyn,

and while some of it is in existence now, so little care was taken as to time and manner of laying or name of the contractor that the experiment has been of little value.

Indian Territory Asphalt.—The asphalt deposits of Indian Territory are located in the southwestern part of the territory in the Arbuckle Mountains, near the Washita River. They extend over an area of several square miles. The asphalt is found in sand and also bituminous rock. The former contains 16⅞% and the latter 21% of bitumen. The sand asphalt is used in its natural state in pavements. It is heated in a special apparatus and laid in much the same way as the European rock asphalts, but to the rock asphalt 50% of sand asphalt is added before heating, when it is laid as before. Nearly all the work in the development of this deposit has been done during the past eighteen months, the charter for the company from which the present operators leased it having been granted in 1895; consequently very little pavement has been laid with this material, that little being principally the repairs of other pavements. Where used, it has so far given good satisfaction, though from its amount of bitumen it might be expected to make a pavement that would be too soft.

By a process of refining, a bitumen of about the consistency of maltha is produced from the sand asphalt. It is first separated from the sand by being boiled in water. The asphalt, having a smaller specific gravity than water, rises to the surface when it is skimmed off and still further refined as required.

European Asphalt.—The European asphalts, although somewhat scattered, are found under about the same conditions. They exist in strata of varying depths, from 6 to 23 ft. in thickness, separated from each other by impermeable beds of limestone.

It is supposed that at an early period bitumen must have been vaporized by extreme heat, that the hydro-carbon while in a state of vapor was forced through this limestone while soft, much as subterranean water follows layers of gravel confined by beds of clay or stone, and that fissures in the overlaying rock have permitted the vapor to pass to the other soft strata above. The rock absorbed this vapor to a greater or less extent, and the geological changes occurring in the succeeding years produced the rock asphalt as it is found to-day. To make a good pavement this rock should contain from 9.5% to 10% of

bitumen, according to conditions. If one deposit contains too much, it can be mixed with another compound containing less. According to the solvents used, the products of the same mine will produce different results, and that may account for the results given here from three different sources. The bitumen and carbonate of lime form so very large a percentage of the whole that the other ingredients are not considered.

Ragusa.		Seyssel.		Val de Travers.	
Bit.	Carb. of lime.	Bit.	Carb. of lime.	Bit.	Carb. of lime.
9.72	88.75	8.15	91.70	12.00	....
8.92	88.21	9.10	90.35	7.20	....
....	....	7.00	....	10.25	88.40

Pavements.—In 1854 a pavement of rock asphalt was laid on the Rue Bergère, Paris, as an experiment, with such success that four years later another trial was made on Rue St. Honoré, from which time may date the beginning of asphalt pavements. In London the first pavement similar to this was laid in 1869, and in Berlin in 1873.

Asphalt as generally laid in this country is simply a bituminous concrete, the sand acting as the body of the mixture, the asphalt simply cementing the particles of sand together.

The success of the European pavements led investigators of this country to make experiments in their own behalf, and from 1870 to 1873 quite a large area of pavement was laid with coal-tar instead of asphalt as a binding material. These pavements failed, as the coal-tar was apt to crack in the winter and be soft and sticky in the summer; or, in other words, a pavement made of coal-tar that would not be soft in hot weather would crack and crumble when the weather became cold. Chemically there is not much difference between coal-tar and asphalt; in fact, the author was once told by an eminent chemist that he knew of no chemical test by which the presence of coal-tar could be detected in asphalt. If, however, it exists in any amount it can readily be discovered by its odor.

The failure of these pavements led to further investigation on the part of interested people, and in 1870 a bituminous pavement* was laid in Newark, N. J., around the City Hall, followed in 1871 by one in New York, near the Battery, with Trinidad asphalt as the cementing material.

* There is some doubt as to the composition of the Newark pavement. The records do not say whether it was asphalt or a coal-tar mixture.

About the same time a similar pavement was laid in Philadelphia, and a few years later others in New York. These experiments were so successful that they attracted the attention of the authorities of Washington, and in 1876 a commission appointed under the authority of Congress reported in favor of paving Pennsylvania Avenue with asphalt, using the European bituminous rock on one portion and Trinidad asphalt for the remainder. From the completion of that work dates the complete success of asphalt pavements in the United States, and although a great amount of careful study and further investigation was necessary, the industry has been continually on the increase since that time.

Some eight or nine years ago, in making his annual report to the city council of Omaha, the author had occasion to say that stone and asphalt were the only real paving materials. The experience of the years since then has only made stronger that belief. For a street subjected to heavy traffic there can be no question that granite properly laid makes the best and most economical pavement, but for a moderate traffic, on reasonable grades, asphalt will give the most general satisfaction. It is smooth, almost noiseless, and can be kept clean. As a sanitary pavement, it is without a rival. It is said to be expensive, and it is to a certain degree, but very few who use it will question the value received. The question of cost and durability will be discussed more in detail later. Some asphalt pavements have failed, but that is not surprising when it is considered how new the industry is, how rapidly it developed, and that all facts about its construction had to be established by pavements actually in use.

The question of how steep a grade it is safe to lay asphalt on has received a great deal of study. Originally grades of even 4% were considered prohibitory, but as more work was done, this was seen to be too conservative a view. Asphalt is now in use upon grades in different cities, as follows: New York City, 6%; Omaha, Neb., 7% to 8%; Brooklyn, N. Y., 4½%; Syracuse, N. Y., 7 per cent.

The objection to steep grades is, of course, the liability of horses to slip down. Contrary to the general belief, asphalt itself is not slippery. It is smooth, and any soft substance upon a smooth surface makes it slippery, but on steep grades foreign matter is less liable to collect than on light ones. The remedy, then, is to keep the pavement clean. It is a fact known by all teamsters that it is harder for a horse

to travel on a smooth pavement when it first begins to rain than after a heavy shower when the surface has been washed clean. In view of the experience of the past few years and the fact that all pavements are kept much cleaner than in former times, the conclusion is reached that grades of less than 5% need not be questioned when considering the advisability of laying a smooth pavement, and in extreme cases those as high as 6% are permissible.

The question of crown or convexity is pertinent here. Streets are paved for use, not for looks, and the cross-section that accommodates travel the best and will carry all water falling upon it to the gutters is the one that should be adopted. Some engineers have a formula for this, based upon the grade of the street and width of roadway. Theoretically this is correct, but in practice it is better to establish a minimum crown and vary from it only when it is absolutely necessary to prevent water from standing on the surface. For a roadway 30 or 34 ft. in width, the following cross-section will give satisfaction at minimum grades. Depth of gutter 5 ins., center of street 1 in. below level of curbs, the cross-section of the street being an arc of a circle. This gives the center half of the roadway with a fall to the sides of 1 in. in 7½ or 8½ ft. as the case may be. This is practically level as far as travel is concerned, and for drainage purposes is about 1%, which is ample. On an asphalt street with level curbs the gutters need never be more than 6 ins. deep unless the width be extreme, and the crown of the pavement preferably not higher than the curbs, so that for widths of 50 or 60 ft. between curbs, the crown should not be more than 6 ins.

It often happens that in repaving old streets, one curb is found at a considerably higher elevation than the other. The practice then is to make the gutter on the high side of maximum depth, and that on the lower side of the minimum, thereby reducing the difference in the roadway as much as possible. If the elevation of the pavement at the quarter instead of the center be made the highest part of the roadway, the most acceptable cross-section is obtained. Some engineers in such cases advocate laying the pavement with a plane surface from gutter to gutter. By this method the side slope is minimized, but the water is all thrown into one gutter, and it is almost impossible to have work carried out so perfectly that settlements will not show in pavements so laid, holding water after every rain.

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Character of Asphalt.—To make a first-class pavement the asphalt should be a good material, properly mixed and well laid upon a good foundation. Whether an asphalt will or will not make a good pavement can only be told by trying. A chemist can analyze an asphalt, tell what are its component parts, and give his idea as to what it ought to do, but the author doubts if any one would be willing to give a definite opinion as to its action in a pavement simply from a laboratory analysis. Stevenson Towle, M. Am. Soc. C. E., in speaking of the partial failure of the Eighth Avenue pavement in New York City, said:*

"This asphalt was submitted to and approved by experts and chemists before the contract was entered into. Soon after the pavement was laid and before its completion (it has never been accepted), it showed unmistakable evidences of disintegration. This failure was exceptional and the experts and chemists who had approved of the asphalt could not account for it. My own belief was that the asphalt was inferior or lacking in some essential property unknown to chemists."

Personally the author would hesitate before giving a final judgment on a pavement that had not passed through at least two winters. An analysis of the refined asphalt is required to ascertain the quantity and quality of the bitumen contained. Then, by former experience with other similar asphalts, and many experiments, the quantity of flux is determined, taking into consideration the climate and amount of traffic.

In this connection, Trinidad asphalt is generally taken as a standard, not because it is the best, but because it is known it will make a good pavement. Any refined asphalt that contains from at least 50% or 60% of bitumen which is composed of approximately 75% petrolene and 25% asphaltene, is deserving of careful investigation and experiment.

Foundation.—The foundation is the important part of an asphalt pavement. The surface coat is only the carpet; the base must be the floor that sustains the load. No matter how good the top may be, a failure in the base means immediate failure in the pavement. Probably the best foundation and the one most generally in use is made of hydraulic cement concrete. Its thickness varies with the traffic, but should never be less than 6 ins. Some seven or eight years ago, the

* See his Report to the Commissioner of Public Works of New York City, January 5th, 1895.

asphalt companies, wishing to reduce the cost of their pavements wherever practicable, experimented with a broken stone base. This stone was of the ordinary size for concrete, and, after being spread upon the prepared roadbed, was thoroughly compacted with a steam roller. Upon the broken stone was then sprinkled hot coal-tar, in quantity about 1 gall. per yard, followed by the binder course. This considerably reduced the cost of the work, but as the solidity of the pavement depended directly upon the ground beneath, its use was soon discontinued. In repaving streets, however, it is often well and desirable to retain the old material as a base. This has been very generally done, and with good results, on granite or other stone streets. A few cases where asphalt was laid over old Nicholson pavements resulted disastrously, as might have been expected. One objection to using the old stone base is that the cross-section of the street often needs to be remodeled, involving the relaying of a large amount of the stone. This requires great care to avoid future settlements. On cobble streets chuck holes and other irregularities often exist, too large to be filled economically with binder. In such cases the street can be brought to the proper cross-section with broken stone thoroughly rolled, the old cobble still being the real foundation.

Asphaltic Cement.—The first step in the actual mixing is the preparation of the asphaltic cement. A portion of refined asphalt is carefully weighed and deposited in an iron tank and melted. After it has attained a temperature of about 300°, the flux is added. If this be petroleum residuum, it is added in a proportion of from 16 to 20 lbs. for each 100 lbs. of asphalt, according to the consistency desired. The temperature is then maintained for about ten hours, the whole mass being kept constantly in agitation by means of an air blast to ensure a thorough mixing. The quantity of the oil will vary a little according to its quality, as well as that of the asphalt itself.

An ingenious machine has been invented for testing mechanically the asphaltic cement. This apparatus consists of an arm some 17 ins. long, supported at one end and provided at the other end with a cambric needle above which is placed a weight of 100 grams. The needle end is connected by a rod and cord with a large hand that moves around a dial divided into 360°. By a spring attachment the needle is brought into contact with the asphaltic cement for any desired time, and the amount of penetration marked in degrees on the dial.

For comparative tests it is of course important that all samples be used at the same temperature. This can most easily be accomplished by placing the cement in water when ready for the test and keeping it at the required temperature, generally from 75 to 80° Fahr. The author knows of no place where this machine is extensively used except in Washington. The report of the Engineer Commissioner for the year ending June 30th, 1895, gives the average penetration of the product of three companies at 77° Fahr. as 69, 73 and 85. In the following year the average of the cement furnished by one of the above companies was 75.

The residuum oil should have a specific gravity of about 20° Beaumé, a flash point of 300° Fahr., and should distil not more than 9% or 10% in ten hours at a temperature of 400° Fahr.

If maltha or some other flux be used, it should be treated practically as above, modified according to the properties of the particular material.

Wearing Surface.—Asphalt pavement was first laid in two layers, a cushion coat of ½ in., and a wearing surface 2 ins. in thickness. After some experience it was seen that the upper surface sometimes slipped on the lower, or the whole slipped on the concrete, thus forming a wavy and uneven surface. To counteract this, there was laid instead of the cushion coat, the so-called binder. This consisted of clean broken stone, cemented together with coal-tar, but later, on account of the variableness of the tar, asphaltic cement was substituted as a cementing material. The thickness of this binder is 1 or 1½ ins. As its object is simply to connect the wearing surface with the concrete, there appears to be no good reason for making it more than 1 in. Where binder is used, the wearing surface is 1½ or 2 ins. thick according to the traffic, the general practice being where the binder is 1 in. to make the wearing surface 2 ins., so as to have the pavement in no case less than 3 ins. thick.

The stone for the binder should be thoroughly clean, and vary in size from ½ in. in its smallest to 1 in. in its largest dimensions. It should be heated to a temperature of about 300° Fahr., the asphaltic cement added in the proportion of about 20 galls. of cement to a cubic yard of stone and the whole mass mixed till each piece of stone is completely coated. It is then carted to the street and spread upon the concrete so as to give the required depth when rolled. It is neither

intended nor desired to fill all the voids in the stone, and care must be exercised to use no more cement than is necessary to bind the stone together. Should there be an excess, it will rise in warm weather and soften the wearing surface, and cause a failure. Such a case as this came under the author's observation, and an analysis of the asphalt showed an excess of 50% of bitumen. The mixture for the wearing surface consists of sand, asphaltic cement and pulverized limestone. The exact proportions vary according to conditions, but in the vicinity of New York are approximately: sand, 710 lbs.; asphaltic cement, 110 lbs.; pulverized limestone, 60 lbs. These proportions will vary according to the character of the sand and amount of bitumen in the asphaltic cement, but they should produce from 9% to 11.5% of bitumen in the finished pavement.

In this mixture it is very necessary that all voids should be filled, and the amount of stone dust depends upon the coarseness of the sand. The use of the limestone dust as a filler has a tendency to make the surface hard and slippery. At first it was thought that the carbonate of lime had a chemical effect on the bitumen, but that idea is about given up, and the author believes that if there were used in its place an impalpable powder made of the silicious gravel found on Long Island, the pavements would be improved.

The sand is heated in a special apparatus to a temperature of about 400° Fahr. and elevated to the mixing platform. It is necessary that this temperature should be uniform, as an extreme heat in even a few hundred pounds might burn and destroy quite a quantity of asphaltic cement, and defects would soon develop in the pavement. While the wearing surface is being laid upon the streets, several tanks are kept full of the cement at a temperature of about 300° Fahr. The proportions having been determined, the sand, asphaltic cement and stone dust are thoroughly mixed in a pug mill for 1½ minutes, when the mixture is dumped into carts below. It should be delivered on the street at a temperature of from 250° to 275° Fahr., and experience has shown that when covered with canvas it will not lose more than 10° or 15° of heat for ordinary distances and temperatures. After being dumped on the binder, it is raked smooth and even, so as to give the required thickness after having received a compression of 40 per cent. This depth can be regulated by a good foreman with experienced rakers. The first compression should be applied with iron

rollers worked by hand. Hydraulic cement is then lightly scattered over the surface, when it should be rolled with a steam roller of 4 or 5 tons, followed in a short time by a third, weighing from 250 to 300 lbs. per inch of width. The object of the different rollers is to apply the weight gradually so as to have the whole compression vertical, rather than with a push, which might occur if too heavy a weight were applied before the material had received a partial compression, thus giving a wavy surface. The rolling should continue as long as any compression takes place, and approximately about five hours for each 1 000 yds. of completed pavement.

Too much attention cannot be given to the rolling, for upon this depends the success of the whole work. Unless thoroughly compressed, the material will have very little cohesive strength. The necessity of this was once impressed upon the author when a street was paved late in the season; and soon after its completion, the mercury fell considerably below the freezing point. This street was one of some thirty contracts that had been completed by the same contractor with the same material, all of which had given perfect satisfaction. In a few days the surface of the pavement began to pick up under travel and the contractor voluntarily relaid a portion of it. For a time it looked as if the entire block must be taken up, but the weather suddenly grew warmer, softening the material so that it would compress under travel, and in a few days the street was perfectly smooth and has remained so ever since. Had the weather remained mild for a few weeks after the work was completed, no trouble would have ensued. The rolling should be begun as soon as the material is leveled off, and continued to completion. Whenever the width of the street will allow it, the rollers should be worked across the street, and on lesser widths diagonally from side to side so as to remove any slight irregularities of surface that might be produced by a continuous rolling in one direction. It is always difficult to get perfect compression along the curb. Consequently it is customary to paint the gutter for a width of about 1 ft. with asphaltic cement, so as to fill completely any pores that might be left open by lack of compression. This cement should be applied before the pavement has become cool, and well ironed with irons specially made and heated for the purpose.

Rock Asphalt.—Rock asphalt is taken from the mines and shipped to this country in its natural state. After being mixed in the propor-

tions determined upon, it is first crushed with rollers and then reduced to a fine powder by being passed through disintegrators, after which it is sifted through sieves to separate any lumps that might otherwise get into the pavement. This powder is then heated in a cylinder, which is kept constantly in motion to allow the air to circulate freely among the particles, and kept for about two hours at a temperature of 300° or 325° Fahr. The material is then carried in carts to the street and spread upon the prepared base to a depth that will give the required thickness when thoroughly compacted. A light roller is then run over the surface to give the initial compression, when workmen, each with a round iron rammer 6 or 7 ins. in diameter, carefully go over the portion of the street covered, all striking blows in unison on the asphalt until it is well compacted. A thin coating of hydraulic cement is spread over the surface when it is ready for the final rolling, which is done by steam and preferably with an arrangement inside the roller for keeping it hot. About twelve hours after the rolling is completed and the material has become cold, the street can be thrown open to travel, which continually adds to the compression already given.

Asphalt Block.—A form of asphalt pavement different from those just described is that composed of asphalt blocks. Pavement of this kind was first laid in San Francisco in 1869. The results were not good, but the promoters were sufficiently encouraged to continue the experiment with improved appliances until its success was assured. The blocks are generally 4 x 5 x 12 ins., but are sometimes made but 4 ins. deep where the travel is light or the foundation particularly good. They are made by mixing broken stone with asphaltic cement and subjecting the whole to a heavy pressure. Limestone has been used; trap rock is preferable, where it can be obtained, as it stands the action of the weather and traffic much better. The stone is crushed to a proper size, and after being screened is heated to a temperature of from 300° to 350° Fahr., when the asphaltic cement and a little pulverized limestone are added and the whole thoroughly mixed. The mixture is then placed in molds and a pressure of 3 000 lbs. per square inch applied until the mass is thoroughly compacted, when it is at once cooled under water and is ready for use. The proportions generally used are 73% broken stone, 13% asphaltic cement, and 10% pulverized limestone, the amount of the last varying with the size of the stone.

It is claimed by the advocates of this pavement that the blocks, being made separately, each one receiving a regular and uniform pressure, will give better results on the street than sheet asphalt. They also claim that, on account of the size of the blocks, a concrete base is not necessary, but one made of broken stone or gravel thoroughly compacted with a steam roller is sufficient, or if concrete be used the depth of the concrete can be reduced. When the foundation is prepared, the blocks are laid upon it practically as stone blocks are, care being taken to make close and straight joints across the street. This form of pavement has been laid in many eastern cities, but in and around New York does not seem to be able to compete successfully with sheet asphalt.

Cost and Maintenance.—When it is considered under what conditions and for what length of time asphalt pavements have been laid, it is not strange that reliable data as to first cost, as well as to repairs, are not at hand. Asphalt has almost always been laid with a guaranty to keep it in good repair for a period varying from five to fifteen years. The price bid has, of course, included the cost of maintenance for the guaranteed time. Throughout the West, when this pavement was first laid, it cost for years $2 95 per square yard on 6 ins. of concrete. The introduction of new asphalts, together with competition, has somewhat reduced this price, so that contracts have been made in Omaha for asphalt pavement on a 4½-in. concrete base for $2 07 per square yard, with a five-year guaranty, and in St. Paul for $2 53 and in Minneapolis for $2 43 per square yard, both of these being on 6 ins. of concrete, with a ten-year guaranty. Brooklyn has let several contracts for $1 58 per square yard on a 6-in. concrete base, with a five-year guaranty, while the Fifth Avenue pavement in New York will cost $4 60, with a guaranty period for fifteen years. Taking all conditions into consideration, these last two prices are probably as low as any received in this country.

Different cities have different methods of making their repairs. When the guaranty periods began to expire in Omaha, in 1888 and 1889, the Barber Asphalt Paving Company entered into contract with the city to keep all their pavements in good condition for a further period of ten years for 8 cents per yard per year, making the entire cost for fifteen years $3 75. Since then, however, contracts have been entered into for a specified price per yard of material actually laid.

In Buffalo the latter method is adopted, the contractor agreeing to keep each patch in repair for a term of years. This necessitates the exact location of each patch as it is made, and in a few years the patches overlap each other, involving a large amount of work in keeping up the record.

In Washington it has been the practice to pay a specified price per cubic yard for all material used. This plan requires inspectors thoroughly conversant with their business, so that defects in material or workmanship can be readily detected.

In Buffalo, where the cost of repairs has been kept with a great deal of care, the expense has been as follows:

Years maintained.	Cost per yard per year.	Years maintained.	Cost per yard per year.
1	$0.017	7	0.0778
2	0.0305	8	0.028
3	0.038	9	0.0122
4	0.0917	10	0.025
5	0.0678	11	0.0353
6	0.0463		

The average for the above is $0.055 per square yard per year.

In Washington the resurfacing and repairs from 1879 to 1895 cost $0.077 per yard per year. During this time 676 390 sq. yds. were entirely relaid, at an average cost of $1 51 per yard. Deducting this cost from the above, the expense of actual repairs was $0.023 per yard per year. During the last two years a device has been used which has considerably decreased the actual cost of repairing asphalt. This consists of an apparatus by which a concentrated gasoline flame is thrown upon the pavement, heating it to such a degree that all the dead and inert material can be easily scraped off and the surface roughened with toothed hoes, so that the new material can be laid and compressed to give a good bond with that already on the street. By means of this machine, repairs can be made much more rapidly and neatly.

The question of repairs and how they should be made is one of great importance. It seems to the author that the method which will give the best satisfaction is to award a contract to responsible parties to keep a certain number of streets, or all in any city if the yardage be not too great, in repair for a term of five years for a specified price

per yard per year, including all streets of which the guaranty expires during the contract period. Provision should be made, of course, to reserve enough money till final payment to ensure the carrying out of the contract. By this plan it would be for the contractor's interest to keep the streets in good condition at all times, as that old proverb, "a stitch in time saves nine," can never be applied with more force than to the repairs of an asphalt pavement.

The life of the pavement varies much with conditions. Some require entire resurfacing inside of the first five years, others are reported to have lasted ten or twelve years with merely nominal repairs. In the light of present experience it would seem that asphalt on a street of ordinary traffic under normal conditions ought to last from twelve to fifteen years before requiring relaying, and should not cost more than 6 cents per yard per year for maintenance after a five-year guaranty period.

This industry, which was just being thought of in 1870, and was still in its infancy in 1880, has now assumed vast proportions. On January 1st, 1897, there was laid in this country, as nearly as could be ascertained, 27 468 915 sq. yds. of asphalt pavement, divided as follows: Trinidad asphalt, 21 527 415 sq. yds.; Bermudez asphalt, 697 500 sq. yds.; Alcatraz (California) asphalt, 916 000 sq. yds.; Standard (California) asphalt, 200 000 sq. yds.; foreign rock asphalt, 603 000 sq. yds.; Utah rock asphalt, 293 000 sq. yds.; other asphalt in the Pacific Coast States (estimated), 1 032 000 sq. yds.; asphalt block, 2 200 000 sq. yds.

Of this amount Buffalo contains more than any other American city, having at the present time 3 663 402 sq. yds. Washington, D. C., comes next with 2 554 262 sq. yds. on June 30th, 1896; this amount includes 477 416 sq. yds. of coal-tar and concrete pavement not considered in the above grand total, but excludes 170 229 sq. yds. laid in the suburbs.

Asphalt in Europe.—The principal cities in Europe having asphalt pavements are London, Paris, Berlin and Vienna. These are all laid with the rock asphalts heretofore spoken of, being called in France *asphalte comprimé*, and in Germany *Stampf-Asphaltum.*

The amounts in these cities are as follows: London proper, 208 000 sq. yds.; Paris, 403 000 sq. yds.; Berlin, 1 600 000 sq. yds.; Vienna, 93 000 sq. yds.

The original cost per square yard on a concrete base 6 to 8 ins. thick was \$3 25 in London, \$3 60 in Paris, \$2 77 in Berlin, and \$3 in Vienna.

The cost of repairs per square yard per annum was 6 to 44 cents in London, 47½ cents in Paris, and 10 cents in Berlin, for a period of fifteen years after the guaranty expired. On railroad streets 15 cents for space between tracks and for a distance of 27½ ins. (70 cms.) outside.

In considering the cost of maintenance of European asphalt pavements, the large amount of traffic they sustain must be taken into account. A report of the Chief Engineer of Paris gives this traffic as follows, the figures being the number of vehicles passing in twenty-four hours:

PARIS.

Rue de Rivoli	42 035	Rue Auber	14 082
Rue Croix des Petits Champs.	20 480	Avenue de la Grande Armée.	8 149
Rue St. Honoré	19 672		

LONDON.

King William Street	26 793	Holborn Viaduct	12 158
Gracechurch Street	15 585	Newgate Street	13 128
Queen Victoria Street	16 531	Moorgate Street	11 398
Cheapside	15 206	Cornhill	9 572
Aldgate	14 200		

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THE FINANCIAL MANAGEMENT OF WATER-WORKS.

By E. KUICHLING, M. Am. Soc. C. E.

TO BE PRESENTED MAY 19TH, 1897.

The questions involved in the financial management of a municipal water-works system are often very interesting, even though they may be somewhat complicated, and it is doubtless owing to the difficulties encountered in the analysis of the problem that no generally accepted principles of such management have yet been formulated. Various methods of procedure have been adopted in different places, but rarely has it happened that any one of them received general approbation or was adopted elsewhere without more or less modification. In most places the exercise of sound judgment is hampered by considerations of expediency, and hence temporary or superficial plans of financial management are in vogue which must sooner or later be materially amended.

Much confusion is also caused by the careless use of terms in the discussion of the subject, as well as in the classification of the various items of income or expense. That which is treated as a maintenance or repair account in one city will often be charged to construction in

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meetings, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

another place, and in some cases the cost will be divided arbitrarily between the two accounts. Again, a distinction is sometimes made between the maintenance and the repair accounts, and when renewals or improvements of any part of the works are made, a separate account may be opened. It is therefore necessary to examine the financial statements relating to the water-works of different cities with the utmost care in order to avoid serious error in making comparisons.

These facts, along with the scarcity of well-digested literature on the subject, were forcibly brought home to the author in the course of an extended investigation of the financial features of the municipal water-works with which he is connected. The inquiry was made by a committee from another branch of the city's government, and the questions which arose seemed at first easy of solution. Upon further reflection, however, the strict equities in the case did not appear so simple, and precedents for conflicting opinions were eagerly sought in the experience of other large communities. A large number of municipal reports, technical journals and society transactions were consulted in the hope of finding therein some clearly defined general principles of financial management for costly public works, but, unfortunately, those which were available at the time contained few useful references to the matter and no extensive discussions. It, therefore, devolved upon the author to formulate his own views in the premises, and the greater part of the following paper was prepared before the appearance of the valuable article * on the same subject by Freeman C. Coffin, M. Am. Soc. C. E.

This explanation and early reference to Mr. Coffin's work is made both on account of the similarity of the arguments in the two papers and to avert the charge of wholesale plagiarism on the author's part. It is also proper to state that in preparing the present paper, the author has in some instances availed himself of Mr. Coffin's expressions, for which due acknowledgment is herewith made; and although the subject is now no longer new, yet it is believed that the further discussion of sound administrative policy in the management of expensive public water-works cannot fail to be of interest to the engineering profession in general. The paper is accordingly submitted with the hope that it will elicit some account of the financial conditions and policies which prevail in other municipal water departments, so that when similar

* See the *Journal* of the New England Water-Works Association for September, 1896.

investigations are made hereafter, a useful fund of pertinent information may be at hand.

Expenses.—In dealing with the annual expenses or charges against a water-works system, the following items are to be taken into consideration:

I. The interest on the bonded debt incurred for construction.

II. A yearly payment into a sinking fund for the ultimate liquidation of the bonded debt.

III. A yearly payment into a fund for the periodical renewal of the perishable parts of the works.

IV. The yearly operating expenses, including ordinary repairs and minor betterments.

V. The average cost of the usual yearly extensions or improvements of the distributing system.

VI. A yearly contribution to a fund for the payment of anticipated future extensions of, or additions to, the supply system.

VII. The interest on all capital expended for construction over and above the bonded debt.

VIII. A profit on the investment in addition to the preceding items.

In the case of successful private corporations, all of these items are taken into account, directly or indirectly, in fixing the rates charged for the service, goods or product, and it is frequently claimed that the same practice should be followed in the case of municipal water-works. Careful reflection, however, will lead to the conclusion that such a course is generally inexpedient, for the reason that a service undertaken by a community for its own exclusive benefit, and through its own government, is essentially a co-operative or mutual enterprise, the product of which is expected to be sold at cost to the participants; also because it is manifestly absurd to demand that one branch of the municipal service shall yield a profit in order that the work involved in another department may ostensibly be performed for less than its true cost.

Strictly considered, the expenses of each department of a city's government should be tabulated separately, and the proper value of any service rendered, or materials furnished, by one department to another should be duly credited and charged in the respective accounts. By this means alone will the real cost of any department, as

well as the value of any service rendered by it, become known, and whenever it may be deemed expedient to make the revenue of such department large enough to yield a profit or surplus over its legitimate expenses, the fact should be distinctly announced and the reasons therefor intelligently explained. Under ordinary conditions, however, it seldom happens that a community deems it proper to make an appreciable profit from any service rendered to the citizens, and hence this item may at once be eliminated.

It is also very unusual for communities to demand from citizens payment for interest on past cash expenditures for the construction of public works, or to require of them annual contributions for the creation of a fund which is to be expended at some distant future time for building prospective new works. The principles here involved are, on the one hand, that an adequate benefit has been derived from past payments, and on the other hand, that there is no obligation on the present generation to provide for remote future demands. No extended argument in support of these two principles appears to be necessary, it being understood that the future demands mentioned relate to entirely new works instead of to the proper maintenance of the existing ones; and hence the sixth and seventh items in the foregoing list may fairly be omitted.

With reference to the fifth item, which is a provision for the usual yearly extensions and improvements of the system of distributing pipes, in order that the service may keep pace with the ordinary increase of population and development of urban territory, it may strongly be urged that inasmuch as such increase is often quite variable, no definite limit to the annual provision can be assigned, and that the required sums for this purpose shall be fixed each year in proportion to the necessities. By this method the annual extensions of the pipe system will properly come under the head of construction, and be paid for by general taxation, as in the past. It must also be borne in mind that all such extensions are presumed to involve immediate benefits fully commensurate with the outlay, and that the tax on the additional valuation of property ensuing therefrom will ultimately repay the investment. The fifth item may therefore likewise be omitted from the list of charges against the works.

Accordingly only the first four items of expense are left to be met by the revenue derived from the works, viz., the interest on the bonded

debt, the sinking fund provision for the ultimate liquidation of this debt, the depreciation fund provision for the periodical renewal of the perishable parts of the works, and the annual operating expenses. Of these, the second and third are frequently combined into a single item, and may form a large or small percentage of the total yearly cost, depending upon the proportion of the aggregate amount which is left to posterity to pay. With regard to the first and fourth items, it is obvious that they should be paid in full by the present inhabitants, and that the financial burden of the next generation should not be increased by any portion of these expenses.

Concerning the provision for sinking and depreciation funds, a considerable diversity of practice is found. In some cities it has been assumed that the generation which incurred a certain bonded debt for a water-works system should provide for its payment in full, besides leaving an adequate surplus for the renewal of the perishable parts of the system, so that the succeeding generation will inherit the works entirely free from debt and with its perishable parts renewed. In other places, however, this plan is regarded as much too generous, and provision is made only for maintaining the works in good order, so that posterity shall not have on its hands a worn-out or greatly depreciated plant, in addition to the original debt. A third plan is for the present generation to provide for the payment of so much of the bonded debt as relates to the perishable parts of the works, leaving the remainder to be taken care of by posterity, and also to provide for the proper maintenance of the plant so as to leave it in good condition.

From the meager data available, it seems that the usual practice in American cities has been to provide only for a general fund which may be used at its maturity, either for renewing a part of the works, or for paying off a portion of the bonded debt, but which is not sufficient for both purposes. The object has been merely to keep the finances of the works in tolerable equilibrium from time to time, so as to prevent the present generation from imposing undue liabilities upon its successor, but without leaving to it very good assets, or works from which it will derive much benefit except at the expense of more or less reconstruction. By this plan the works never become free from debt, but if they are maintained in good order, their value may be equal to the bonded liability. This condition is essential to solvency, and is ac-

cordingly the lowest limit in the financial scale to which the works should be allowed to fall.

A somewhat safer plan to follow is the third one indicated above, by which provision is made not only for the renewal of the perishable parts of the works but also for the extinction of the original cost of these parts. The plant will thereby be turned over to posterity partially paid for and in good condition, or with the means for putting it into such condition. To the extent of their capacity the works will then serve the future as they did the past or present, and it is therefore proper that the future should bear at least the cost of the permanent portions, as well as the subsequent renewals. The burden is thus divided between two or more generations, each paying a reasonable share of the total original cost; and at the same time, some consideration is expressed for the greater expenditures of the future, which will assuredly come with increase of population and the constant demands for the improvement of the general welfare.

In relation to the life of the perishable parts of a water-works system, little definite knowledge is yet available. Pipes and their appurtenances may last for from twenty to fifty years, according to circumstances, while steam boilers and pumping machinery may have to be renewed more frequently ; but in general it may be assumed that with the changes rendered necessary in a growing city by the gradual development of residential into commercial districts, the costs involved in maintaining a proper standard of efficiency for the works are practically equivalent to a renewal of the perishable parts of the plant every thirty years. The same period of time has also been generally adopted as the duration of the sinking fund for liquidating the bonded debt of the works ; and until better statistics have been gathered, this limit may be accordingly adopted for the maturity of both funds.

To exhibit the English practice in regard to the repayment of loans for the construction of public works, it may be mentioned that out of 223 loans, amounting in the aggregate to nearly $5 000 000, made by the Local Government Board to various communities in 1874, about 61% of both the number and the amount of money was for a period of thirty years ; 5.8% of the number and 15.5% of the amount was for periods from thirty-one to fifty-seven years ; while the remainder of both number and amount was for periods less than thirty years ; and

similarly in 1892, out of 1 122 loans sanctioned by the same Board to urban and rural sanitary districts, 41.5% was for thirty years, 10.6% for from thirty-one to fifty years, and 47.9% for less than thirty years. Furthermore, out of the 104 loans made in the latter year for a period of fifty years, 89 were specifically mentioned as being for the purchase of land, thus recognizing the principle that the payment of the cost of the permanent parts of public improvements may fairly be transmitted to posterity in some degree.

As the gradual formation of a fund by a series of annual payments is generally understood only in a vague manner outside of financial circles, a few words on this subject may be permitted. Each annual payment is to be invested so as to yield a good rate of interest, which is to be added to the said payment or principal every succeeding year, the interest for such year then being computed on the sum. Compound interest is thus had on each of the annual payments, and the sum of these payments with accrued compound interest constitutes the fund. Expressed in mathematical terms, the annual payment s, which must be made during a period of n years, and will be invested at compound interest at the rate of r % in order to produce a certain ultimate principal or sum p, is found from the equation:

$$s = \frac{r}{(100 + r)\left\{\left(1 + \frac{r}{100}\right)^n - 1\right\}} p.$$

Assuming $n = 30$ and $r = 3$, $s = 0.02041\ p$; or, in other words, the annual payment s made during a period of thirty years and bearing compound interest at 3%, must be about one-fiftieth or 2% of the ultimate required sum p. In like manner, if compound interest at $3\frac{1}{2}$% could be secured on the annual payments, the amount of each such payment would be 1.872% of the sum p; and if compound interest at 4% were obtained, the annual payments would become 1.715% of this sum. In general, therefore, it may be said that the yearly charge against the works for the production of a fund sufficient to pay off the original cost of the perishable parts, or to renew them after a period of thirty years, should be about 2% of such cost, and if both items are considered, the yearly charge should be 4% of this cost.

The foregoing analysis of the problem thus leads to the conclusion that the proper annual charges or expenses of a municipal water-works system should embrace the interest on the bonded debt for con-

struction, a contribution to a thirty-year sinking and renewal fund for the perishable parts of the plant alone, and the operating expenses, including ordinary repairs and betterments. All extensions and material improvements of the system should be regarded as new construction work, to be paid for by general taxation; but a certain percentage of such cost, sufficient to furnish the amount necessary for renewal, as aforesaid, should be charged to the works, since it may fairly be presumed that a corresponding revenue will be derived from such extensions. On the other hand, the works should not be charged with interest on past cash payments for extensions, or for a sinking fund for the same, or for a profit.

Revenue.—Having considered the proper yearly charges or expenses of a municipal water-works, and knowing that the system should have a revenue equal in amount to such expenses, it next becomes of importance to ascertain how this revenue should be obtained. Obviously the entire sum must be paid by the citizens, either by assessment upon all taxable property, or by assessment upon the real estate alone which is served, or by direct charge for the quantity of water actually or presumably used in the premises of each consumer, or by a combination of these charges. The latter method is commonly adopted, inasmuch as a considerable percentage of the water is used for a great variety of general public purposes, and its value should accordingly be paid by a uniformly distributed charge upon all taxable property. In addition to this sum, however, a certain proportion of the total yearly cost should also be paid by general taxation, since a large share of the expense of construction and maintenance is due to the necessary enlargement of the capacity of the pipes, reservoirs, pumping machinery, etc., for the suppression of fires and to provide for the future growth of the community.

In regard to the proportion of the total yearly cost which should be paid by general taxation on account of the initial enlargement of the works for fire, public and future purposes, much diversity of opinion exists. Some contend that this charge should be borne entirely by the present consumers, while others claim that it should be paid by assessment upon all taxable property, in order to make the water rates as low as possible. By the latter class of advocates a sharp distinction is made between taxpayers and water consumers, or, as it may otherwise be expressed, between the taxable property of a community

and the individuals, corporations or civic departments which consume the water; and they insist that inasmuch as the annual cost was incurred for the general public benefit, instead of for individuals, all taxable property should be assessed therefor uniformly, exactly as in the case of the public school, fire and police services. This argument is a very strong one, and appears to have been generally recognized in one form or another, such as the payment of a rental for fire hydrants to private water supply companies, or the payment of a portion of the yearly interest account where the works are owned by the community. It may therefore be assumed that public opinion is generally in favor of the proposition that some part of the yearly cost of the works should be paid by uniform assessment upon all taxable property.

It is obvious that the provision for adequate fire protection and future growth of the community materially increases the cost of construction over that which would be required to furnish only the quantity of water needed for domestic and manufacturing purposes. While the aggregate amount of water used per year for suppressing fires may be but a small percentage of the total supply, yet it must be delivered in large volume during short periods of time and without causing appreciable interference with all other uses. As a consequence, nearly every part of the works must have considerably greater capacity than is required for the service of individual consumers alone; and the same is manifestly true when provision is made for future growth. A number of estimates of the increased cost of construction to afford fire protection alone have been made by several experienced engineers, from which it appears that such increase is at least 60%, or that over one-third of the entire cost is expended for meeting this requirement; and it may also be added that a recent analysis of the cost of the works with which the author is connected has led to practically the same conclusion.

With reference to the provision for future growth of the community, the proportional costs of construction vary from year to year, as the expectations of increase are being realized. Ordinarily, the main features of the water-works of a large city are designed so as to require no enlargement for a period of from twenty to forty years, during which time the population will probably be doubled. The cost of this provision may, in general, be taken at fully 30% of the total original

expense, or about the same as for the fire protection; and as it was incurred essentially with the purpose of attracting other people to become permanent residents of the city and increase its wealth, the investment partakes of the nature of public speculation. In this view of the case, it is proper that the yearly cost of such investment should be borne, in part, at least, by the entire taxable property. By the increase of population, however, the yearly consumption of water gradually becomes larger, and if the price is based on the quantity used, the annual contribution to the necessary revenue from general taxation will gradually diminish, and will cease entirely in this respect after the original provision for future growth is exhausted.

In opposition to this method of securing a portion of the revenue, it may be urged that the entire yearly cost of the said provision should be included in the water rents, on the ground that the taxable property of the community is sufficiently burdened with the other charges previously mentioned. If this plan were adopted, the rates for the use of the water would necessarily be very high in the outset, but might be reduced from year to year as the consumption increases. Such a policy is, however, generally regarded as unwise in commercial circles, since great stress is laid upon low and unfluctuating water rates, whereby a strong inducement is offered to the establishment of new industrial enterprises, which will cause a far more rapid increase of the wealth of the city than can possibly ensue from the slower growth of the residential population alone. When it is argued in such circles that a somewhat higher general tax rate must make up the deficiency in revenue which results from a low price for the water, the answer is promptly given that a moderate addition to the general taxes is so widely distributed as to be practically inappreciable to the great majority of taxpayers, and that the increase in the value of real estate, due to the presence of such industries in the community, abundantly compensates the owners thereof for their slightly higher taxation; whereas, if the same amount were to be added in the water rents, the burden would fall heavily upon the proprietors of industrial establishments, on whose enterprise the prosperity of the public is principally dependent.

There is, however, another excellent reason for making a division of the financial burden between persons and property which is not often considered. This is the average annual saving in the amount of

fire insurance premiums paid by the property-owners, after the introduction of an efficient system of water-works, over that which would be required if the city had no public water supply, and as the loss by fires is never fully compensated by the insurance, there is also the average annual saving in such uncompensated loss to the community in consequence of the operation of the water-works. Even a very superficial investigation of the statistics relating to insurance and fire losses in large cities brings to light the fact that these two savings are of great magnitude, and a close analysis demonstrates that they are often larger than the annual interest charges on the entire cost of the works. Manifestly the benefit thus gained applies mainly to property, although some advantage also results to persons by reason of the greater chance for continuous employment in a city where fires are quickly suppressed.

These considerations also lead to the further fact that the requirements of modern civilization render the development of a large city and the resulting great increase in the value of real estate impossible without an adequate system of water supply or fire protection. In nearly all cases, the appreciation in the value of such property soon after the introduction of water-works becomes much larger than the cost of the plant, and its market price continues to advance steadily with the subsequent growth of population. This rise in value and the reduction in rates of insurance and fire loss are clearly benefits which accrue only to property, as opposed to persons or water consumers, and it therefore follows that an equitable division of the yearly charges should be made between these two elements.

While much more might be said upon the question, it seems to be generally conceded that the water rates of a large city should be as low as possible, and that a considerable proportion of the annual expenses of the works should be paid by general taxation. From the foregoing it has been shown that, on an average, fully one-third of the yearly interest on the bonded debt for a public water supply is incurred for fire protection, and about the same amount for the provision for future growth. The whole of the former and perhaps about one-half of the latter should fairly be paid by general taxation, and in addition thereto compensation should also be allowed at the established rates for the water which is used for general public purposes; the remainder of the revenue required to pay the annual expenses may then be obtained

by charges for the use of the water by all classes of private consumers. Under such conditions, and with the understanding that the interest account includes an adequate sum for sinking fund and depreciation, the works may be regarded as conducted on proper business principles, without discrimination in favor of either taxpayer or consumer.

Application to a Particular Case.—The foregoing principles will now be applied to the case of an inland manufacturing city of 100 000 inhabitants, using on the average 8 000 000 galls. of water per day, and having a gravity conduit with a capacity of 14 000 000 galls. per day, costing $600 000; a distributing reservoir of 40 000 000 galls. capacity, costing $150 000; an efficient distributing system of 150 miles of pipe, ranging from 4 to 24 ins. in diameter, costing $1 600 000; and costs of administration, land, damages, etc., during construction of $650 000; thus making a total original cost of $3 000 000, all of which is a bonded debt bearing 5% interest. It will further be assumed that the cost of the perishable parts of the plant is $800 000; that the probable life of these parts is thirty years, and that this amount of the total debt is not only to be extinguished by an annual payment into a sinking fund, but is also to be on hand for renewing such parts at the end of the time named; also that the yearly operating expenses, including minor repairs, are $50 000.

As was pointed out previously, the annual contribution to a thirty-year sinking fund is about 2% of the amount which is to be accumulated; and since in this case both a sinking and a renewal fund, each in the sum of $800 000, are to be provided, the yearly charges therefor will accordingly be 4% of this amount, or $32 000. Adding the interest on the bonds and the operating expenses, as aforesaid, the total yearly expense account will thus be $232 000. The question now arises as to the proportion of this sum which should be borne by general taxation, it being assumed that the water is to be supplied to consumers without profit, and that the continued prosperity of the community depends upon an equitable division of the annual expense between taxpayers and water consumers.

From the given conditions, it may readily be taken for granted, without further analysis, that fully one-third of the bonded debt was here incurred for fire protection, and another third in allowing for the future growth of the city. The interest on the former sum and about one-half of that on the latter should properly be paid by general

taxation, the amount thus raised being $75 000. To this should also be added some proportion of the annual operating expenses, since the costs of maintenance are manifestly greater with pipes of large diameter than with small ones, and much expense is involved in the care of fire hydrants in winter. A reasonable estimate of such proportion is about one-fifth, so that $10 000 more would be obtained by general tax on this account. Furthermore, the water which is used for various public purposes, such as sprinkling and cleaning streets, flushing sewers, extinguishing fires, constructing new public works, supplying drinking and ornamental fountains, and serving municipal buildings, schools, hospitals, asylums, etc., should also be paid for by general taxation at substantially the same rate as charged to private consumers.

In the case under consideration, it is probable that fully 10% of the gross supply will be used for the public purposes mentioned, in which event the quantity will amount to about 300 000 000 galls. per year. As will be seen subsequently, the cost of the water is about 5 cents per 1 000 galls., so that the value of the quantity mentioned becomes $15 000 per year. Finally, there is the proportional part of the annual contribution of $32 000 to the aforesaid sinking and renewal fund, which should be paid by general tax; and as it may be assumed that not less than one-third of this account relates to general public purposes, such part should accordingly be about $11 000. The total yearly amount to be raised by general tax is, therefore, as follows:

1. For interest on proportional part of bonded debt incurred for fire and future purposes	$75 000
2. For proportional part of annual operating expenses	10 000
3. For value of water used for general public purposes	15 000
4. For proportional part of annual contribution to sinking and renewal fund	11 000
Total	$111 000

The total annual expenses, however, were found to be $232 000; hence, if $111 000 be obtained by general taxation, the remainder, $121 000, should be secured from the private consumers, and the question of the proper charge for the water by meter measurement is reached. As stated in the outset, the average daily consumption in the city is

8 000 000 galls., of which a certain percentage is lost by leakage in the pipe distributing system and its appurtenances. For the present, it may be assumed that such leakage is at the average rate of 3 000 galls. per mile of pipe per day, thus giving a loss in 150 miles of 450 000 galls. per day, or about 5.6% of the gross consumption. There is also a certain loss due to under-registration of meters for which allowance must be made, and no great error will probably be made if the same is taken at 4.4% of the gross consumption, it being assumed that all service pipes are metered. The total loss by these two causes is, therefore, 10%, thus leaving 7 200 000 galls. per day, or 2 628 000 000 galls. per year, available for public and private use; and as the sum of $121 000 is to be obtained by the sale of this quantity of water, the cost price accordingly becomes about 4.6 cents per 1 000 galls. To provide for other contingencies of loss and errors in the various estimated quantities, such cost price may be considered as at least 5 cents in this case.

Fire Streams and Leakage.—In connection with the foregoing financial questions, it also becomes of interest to investigate somewhat more definitely the demands which are made upon the water-works system for fire purposes, and the losses by leakage from the distributing pipes and their appurtenances. The most recent discussions of these two subjects with which the author is acquainted are contained respectively in the valuable paper* on "The Protection of a City against Fire," by John R. Freeman, M. Am. Soc. C. E., and in the equally valuable paper† on the "Consumption and Waste of Water," by Dexter Brackett, M. Am. Soc. C. E. In the former, Mr. Freeman gives his own estimate of the number of fire streams which may be required simultaneously in American cities of various magnitude, together with similar estimates by Messrs. J. Herbert Shedd and John T. Fanning, Members Am. Soc. C. E. These estimates are all in tabular form, and may be combined as on the next page, it being understood that the streams will each discharge from 250 to 200 galls. per minute, and that this number refers to use upon large fires in the commercial and manufacturing districts.

The fifth column of the following table contains the author's estimate of the probable greatest number of such streams that may be

* See *Journal* of the New England Water-Works Association, Vol. vii.
† See *Transactions*, Vol. xxxiv, p. 185.

TABLE EXHIBITING ESTIMATED NUMBER OF FIRE STREAMS REQUIRED SIMULTANEOUSLY IN AMERICAN CITIES OF VARIOUS MAGNITUDES.

Population of community.	NUMBER OF FIRE STREAMS REQUIRED SIMULTANEOUSLY.			
	1 Freeman.	2 Shedd.	3 Fanning.	4 Kuichling.
1 000	2 to 3	....	....	3
4 000	....	....	7	6
5 000	4 to 8	5	....	6
10 000	6 to 12	7	10	9
20 000	8 to 15	10	....	12
40 000	12 to 18	14	....	18
50 000	....	....	14	20
60 000	15 to 22	17	....	22
100 000	20 to 30	22	18	23
150 000	....	....	25	34
180 000	....	30	....	38
200 000	30 to 50	....	....	40
250 000	....	....	....	44
300 000	....	....	....	48

required, as deduced from the replies to a recent inquiry addressed by him to the fire department chiefs of about fifty American cities. For more easy comparison, this table is represented graphically in Fig. 1. It may also be remarked that rare disasters, like the great conflagrations at Chicago, Boston, Lynn, etc., are not considered in any of these

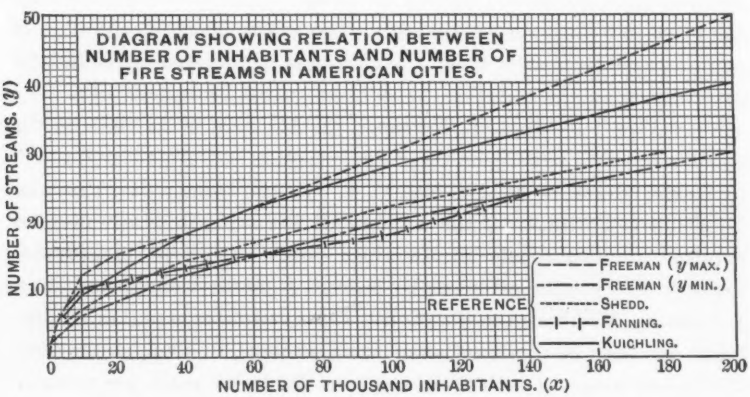

FIG. 1.

estimates, as the local fire departments are usually unable to manage a much larger number of streams without help from neighboring communities.

To determine conveniently the ratio which the total delivering capacity of the distributing system should bear to the quantity

required for ordinary purposes alone, the relation between the number of inhabitants of the city and the required number of fire streams, as well as the ordinary consumption of water, should be expressed analytically. For the former, the author has deduced from the preceding table the following expressions, in which y denotes the required number of streams and x the number of thousand inhabitants:

For Freeman's data: $\left\{\begin{array}{l} y \text{ min.} = 1.7\sqrt{x} + 0.03\,x \\ y \text{ max.} = \dfrac{x}{5} + 10 \end{array}\right\}$ .... (1)

For Shedd's data: $y = \sqrt{5\,x} = 2.24\,\sqrt{x}$ .... (2)

For Fanning's data: $y = \dfrac{x}{10} + 9$ .... (3)

For the author's data: $y = 2.8\,\sqrt{x}$ .... (4)

while for the average ordinary consumption of water, expressed in gallons per head and day, q, Mr. Coffin's formula, as given in his paper previously cited, may be taken:

$$q = 40\,x^{0.14} \quad \text{(5)}$$

A glance at this table or the diagram shows that the author's estimates of y are generally intermediate between the greatest values given by Mr. Freeman and those given by Messrs. Shedd and Fanning; and as the corresponding expression (4) is simple in form, it may be used conveniently in combination with (5), after reducing both to discharge in gallons per minute. For this purpose it will be assumed that each fire stream delivers 250 galls. per minute, and that in dealing with the quantity required for ordinary consumption, the maximum rate of such consumption during the business hours of the day should be considered instead of the average rate for 24 hours. This maximum rate is usually about 1.5 times the average, and hence the total capacity of the main distributing system for a given number, x, of thousand inhabitants, expressed in gallons per minute, should be:

$$Q = \left\{ 250\ (2.8\sqrt{x}) + \frac{3}{2}\,\frac{40\times1000}{1440}\,x^{1.14} \right\}$$

$$= 250\left(2.8\sqrt{x} + \frac{x^{1.14}}{6}\right) \quad \text{(6)}$$

while the capacity required for ordinary consumption alone is:

$$q_1 = 250\ \frac{x^{1.14}}{6} \quad \text{(7)}$$

and that for fire purposes alone is:

$$q_2 = 250\ (2.8\,\sqrt{x}) \quad \text{(8)}$$

The ratio of the total capacity to the quantity needed for ordinary purposes is thus found to be

$$m_1 = \frac{Q}{q_1} = 1 + \frac{16.8}{x^{0.64}} \qquad (9)$$

and inasmuch as the required deliveries Q and q_1 are proportional to the squares of the respective diameters D and d, the following values of the ratios $\left(\frac{Q}{q_1}\right)$ and $\left(\frac{D}{d_1}\right)$ are accordingly obtained for different values of x, or populations of different magnitude.

For $x =$	50	100	150	200	250	300
$m_1 = \frac{Q}{q_1} =$	2.374	1.882	1.680	1.566	1.491	1.437
$\frac{D}{d_1} =$	1.54	1.37	1.30	1.25	1.22	1.20

The cost per lineal foot of the usual cast-iron distributing pipes laid in place, however, may in general be expressed by the formula, $s = a + bd^n$, in which the exponent n is unity for the smaller sizes up to a diameter of about 10 ins., while for larger sizes it becomes about 1.4; hence allowance must be made for this fact in computing the relative cost of the system when provision is to be made for fire purposes. It is therefore seen by this general method of analysis that the estimate of one-third of the original cost of the works for fire protection is not excessive for cities of from 100 000 to 300 000 inhabitants.

With regard to the invisible or undiscoverable leakage from the distributing system and its appurtenances, such as fire hydrants, stop-valves and the street cocks on the service pipes, little information is as yet available, especially in the case of large cities. In the papers previously cited, both Mr. Brackett and Mr. Coffin have given some interesting data about the quantity of water not accounted for in the extensively metered towns of Yonkers, N. Y., Milton, Newton, Wellesley and Fall River, Mass., and Woonsocket, R. I., and have shown that such quantity ranges from 30% to 50% of the whole supply. It appears, however, that some public uses of water and the slip or under-registration of the meters were not included in the estimates, so that the entire loss in these cases cannot fairly be attributed to leakage. In Berlin, on the other hand, the water-works authorities claim

that only about $2\frac{1}{2}\%$ of the supply is lost by leakage, and the question naturally arises why such loss should be so large in American cities and so little in the German capital.

An examination of the different elements of the problem, however, leads to the conclusion that it is entirely improper to measure the leakage by a percentage of the supply. The quantity of water passing through a leaky pipe bears no relation whatever to the loss, and the latter depends only on the size and number of the orifices and the pressure. Thus in a pipe from which no draft is made, the leakage is 100% of the discharge; whereas with a heavy draft, the same loss may become only a small fraction of 1 per cent. A more rational method of expressing leakage is to state the quantity lost in terms of some unit of length and time, such as gallons per mile per day; and when this is done, many apparent anomalies will probably shrink to small proportions.

It should be understood that the leakage here referred to is limited to that which does not show on the surface of the ground, and the individual components of which cannot be detected by the most careful inspection. Loss by wilful waste on the part of consumers and by breakage of pipes is distinctly excluded from present consideration, since the former may be corrected by the use of meters, and the escape of a comparatively large quantity of water at a single point generally renders itself manifest after a short time. The inquiry may therefore be restricted to the loss due to the sweating or slight dripping of the pipe joints, valves of fire hydrants, stuffing-boxes of stop-valves, badly ground taps and curb cocks, and defective joints in service pipes.

From close observation of thousands of water pipe joints and fixtures in various localities, both when first laid and after having been in use for years, the author has reached the conclusion that a discharge of one drop per second from each joint, five drops from each hydrant and stop-valve, and three drops from each service pipe, including tap and curb cock, represents a fair measure of the average undiscoverable leakage in a well-constructed distributing system. As the size of a drop of water, however, depends upon the form and magnitude of the surface from which it falls, a number of experiments were made by the author to determine the weight and volume of one hundred drops falling from a cast-iron surface similar to that of a pipe socket, from

which it was found that one such drop per second is equivalent to about 3 galls. per day. On this basis, and with the assumption that on the average there are 504 pipe joints, 12 hydrants, 10 stop-valves and 100 service pipes per mile of distributing pipe, the leakage will amount to 2 742 galls. per mile per day, or in round figures, say from 2 500 to 3 000 galls. per mile per day.

In comparing these figures and the observed losses at the several places mentioned in the papers of Messrs. Brackett and Coffin, it should be noticed that in all of the cases, more or less unmeasured water was used for public purposes, and no account was taken of the under-registration of the meters; furthermore, there appears to be much uncertainty as to the actual delivery into the distributing pipes, owing to the variable allowance made for slip in the pumps. Considering that with the exception of Berlin and Fall River, most of the cities are small, and that the unmeasured amounts used for public purposes may easily be relatively large, it may be assumed that 10% of the given total delivery, or about 4.5 galls. per inhabitant per day, is thus consumed; and as most meters failed to record the entire quantity of water passing through them, especially for small discharges such as occur from defective house fittings, it will probably be fair to assume that 5% more is attributable to under-registration. These two items may also include the possible error in the allowance for pump slip. For convenience of examination, the essential data may now be arranged in the table on the next page, the last column of which contains the computed leakage.

In the case of Berlin, it has been assumed in the table that only about 2.5% of the total delivery is lost by leakage from the distributing pipes and appurtenances, not because there is any good proof that so slight a leakage exists in that city, but rather to indicate the author's lowest estimate of such loss in a large system, which has been in use for many years, but is maintained in the best possible condition. The claim that only 2.5% of the entire output of the works cannot be accounted for, and that this also includes under-registration of the meters, appears entirely unjustifiable to the author, since large quantities of water are used in Berlin for public purposes, which must necessarily be estimated on somewhat coarse lines. To those who are familiar with the details of municipal water-works, such a close balancing of the accounts cannot fail to be suspicious.

TABLE SHOWING UNACCOUNTED LOSSES OF WATER IN VARIOUS PLACES, TOGETHER WITH ESTIMATES OF LEAKAGE FROM DISTRIBUTING PIPES AND APPURTENANCES.

Locality.	Year.	Number of miles of distributing pipe.	Total delivery in gallons per day. (Q_0)	Quantity not accounted for, being for public uses, under-registration of meters, and leakage of pipes.		Estimated leakage in distributing system, being balance left after deducting from (Q_1) 10 per cent. of (Q_0) for unmetered public uses, and 5 per cent. of (Q_0) for under-registration of meters.	Computed leakage from pipe system in gallons per mile per day.
				Gallons per day. (Q_1)	Per cent. of total delivery.		
Milton, Mass.	1893.	18	128 529	62 687	48.8	43 408	2 411
Newton, Mass.	"	105	1 288 000	595 600	46.2	402 400	3 832
Fall River, Mass.	"	64	2 217 370	942 870	42.5	610 264	‡9 535
Woonsocket, R. I.	"	33	*3 348 000	*748 000	22.4	245 800	‡7 448
Yonkers, N. Y.	"	43	2 623 760	1 010 000	38.5	616 436	‡14 336
Berlin, Germany	1889.	411	20 000 000	800 000	4.0	†534 000	1 300
Author's general estimate.	......	......	....	....	....	....	2 500 to 3 000

With reference to the leakage in the other cities, especially Yonkers, Fall River and Woonsocket, it is proper to state that the large figures exhibited in the last two columns of the foregoing table are purely tentative, and that a closer examination of the actual conditions will doubtless reveal a far better general state of the works than might be inferred from the submitted analysis. The results, however, are instructive, in so far as they point to the exercise of the utmost care, not only in the original construction and maintenance of an extensive distributing system, but also in accounting for the water delivered therein.

* Average for six months from March 1st to September 1st, exclusive of amount used for street watering, fountains, etc., for which a definite estimate is given.

† Least probable quantity as estimated by author, being about 2½% of total delivery.

‡ These quantities are regarded as highly excessive, and are doubtless due to errors in the premises.

Vol. XXIII. MAY, 1897. No. 5.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publication.

CONTENTS.

SOCIETY AFFAIRS.

PAPERS.

ILLUSTRATIONS.

The price of publications is as follows: Proceedings, $6 per annum; Transactions, $10 per annum. Postage will be added when they are sent to foreign countries.

American Society of Civil Engineers.

Vol. XXIII. MAY, 1897. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

May 5th, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 68 members and 9 guests.

The minutes of the meetings of April 7th and 21st, 1897, were approved as printed in *Proceedings* for April, 1897.

A paper entitled "Asphalt and Asphalt Pavements" was presented by George W. Tillson, M. Am. Soc. C. E., and discussed by Messrs. R. W. Lesley, Edward P. North, M. E. Evans and George W. Tillson. Correspondence on the subject from Messrs. F. W. Cappelen and Marshall Morris was presented by the Secretary.

Ballots were canvassed and the following candidates declared elected:

As Members.

John Crosbie Brackenridge, Brooklyn, N. Y.
Philip Hoffecker De Witt, Caledonia, N. Y.
David Leavitt Hough, New York City.
Frank Olin Marvin, Lawrence, Kan.
Louis Younglove Schermerhorn, Philadelphia, Pa.
Charles Mills Slocum, Springfield, Mass.
Samuel Gaylord Tibbals, Brooklyn, N. Y.

As Associate Members.

Western Radford Bascome, St. Louis, Mo.
Richard Lewis Humphrey, Philadelphia, Pa.
Joel Edward Wadsworth, East Berlin, Conn.

The Secretary announced the election on May 4th, 1897, by the Board of Direction of the following candidates:

As Associates.

Henry Lord Norton, Merrick, Mass,
William Anderson Polk, New York City.

As Juniors.

John Maurice Evans, New York City.
Gavin Nelson Houston, Newark, N. J.
Richard Stanislaus McCaffery, Lima, Peru.
George Freeman Rowell, Brooklyn, N. Y.

Adjourned.

May 19th, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 57 members and 5 guests.

A paper by E. Kuichling, M. Am. Soc. C. E., entitled "The Financial Management of Water-Works," was presented by the Secretary, together with correspondence on the subject from Messrs. W. C. Hawley, Freeman C. Coffin and Wynkoop Kiersted. The paper was discussed by Messrs. Rudolph Hering, James Owen, John F. Ward, Henry Goldmark and L. L. Tribus,

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

April 20th, 1897.—Seven members present.

Authority was given for selling the house of the Society, No. 127 East Twenty-third Street, for $60 000, the Society to have the privilege of occupying the premises until its new house is completed.

Adjourned.

May 4th, 1897.—Seven members present.

A Special Committee to report on "The Proper Manipulation of Tests of Cement," was appointed.

The Secretary reported the execution of a contract for the sale of the house of the Society, No. 127 East Twenty-third Street.

The President was authorized to appoint a committee to award the Collingwood Prize for Juniors.

Proposed changes in the rules governing the award of the Norman Medal, Rowland and Collingwood Prizes were considered.

Messrs. Julius W. Adams, George S. Greene, Henry Flad, Joseph P. Davis and A. Fteley were appointed a Committee to prepare a memoir of the late William E. Worthen, Past-President Am. Soc. C. E.

Messrs. O. Chanute, Rudolph Fink and H. G. Prout were appointed a Committee to prepair a memoir of the late Albert Fink, Past-President Am. Soc. C. E.

Applications were considered and other routine business transacted.

Two candidates were elected as Associates and four as Juniors.

Adjourned.

ANNOUNCEMENTS.

ANNUAL CONVENTION.

The Twenty-ninth Annual Convention will be held at Quebec. The headquarters of the Society will be at the Château Fontenac, and the first session will be held on the morning of June 30th, the Convention continuing through July 1st and 2d. The following papers will be presented:

"The Relation of Tensile Strength to Composition in Structural Steel," by A. C. Cunningham, M. Am. Soc. C. E.

"Recent Tests of Bridge Members," by J. E. Greiner, M. Am. Soc. C. E.

"The Power Plant, Pipe Line and Dam of the Pioneer Electric Power Company at Ogden, Utah," by Henry Goldmark, M. Am. Soc. C. E.

These papers are printed elsewhere in this number of *Proceedings.*

At the Business Meeting held during the Convention a number of amendments to the Constitution will be presented.

MEETING.

Wednesday, June 2d, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by D. D. Clarke, M. Am. Soc. C. E., entitled, "The Distortion of Riveted Pipe by Back-Filling," will be presented. It is printed in this number of *Proceedings.*

DISCUSSIONS.

Discussion on the paper by Wynkoop Kiersted, M. Am. Soc. C. E., entitled "Valuation of Water-Works Property," which was presented at the meeting of April 21st, 1897, will be closed June 1st, 1897.

Discussion on the paper by George W. Tillson, M. Am. Soc. C. E., entitled "Asphalt and Asphalt Pavements," which was presented at the meeting of May 5th, 1897, will be closed June 15th, 1897.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

			Date of Membership.
BRACKENRIDGE, JOHN CROSBIE	Chf. Eng., Brooklyn Heights R. R. Co., 168 Montague St., Brooklyn, N. Y.		May 5, 1897
HOUGH, DAVID LEAVITT	19 West 31st St., New York City		May 5, 1897
LUDLOW, JACOB LOTT	Winston, N. C		Mar. 3, 1897
TIBBALS, SAMUEL GAYLORD	148 Milton St., Brooklyn, N. Y.	Jun. M.	May 2, 1888 May 5, 1897
MARVIN, FRANK OLIN	Professor of Civil Engineering, and Dean of the School of Engineering of the University of Kansas, Lawrence, Kan.		May 5, 1897
WILLIAMS, EDWARD GILBERT	Eng. and. Supt. Caribbean Manganese Co., Colon, Republic of Colombia		Feb. 3, 1897

ASSOCIATE MEMBERS.

BASCOME, WESTERN RADFORD	2305 Lucas Place, St. Louis, Mo.	Jun. Assoc. M.	Dec. 3, 1891 May 5, 1897
HUMPHREY, RICHARD LEWIS	(Bureau of Surveys, D. P. W.), City Hall, Philadelphia, Pa		May 5, 1897
MILLER, RUDOLPH PHILIP	141 East 40th St., New York City.	Jun. Assoc. M.	Jan. 2, 1890 April 7, 1897
STOWE, HAROLD CLAIR	28 Orange St., Brooklyn, N. Y.		April 7, 1897
WADSWORTH, JOEL EDWARD	East Berlin, Conn.	Jun. Assoc. M.	Dec. 5, 1893 May 5, 1897

JUNIORS.

EVANS, JOHN MAURICE	112 West 136th St., New York City		May 4, 1897
ROWELL, GEORGE FREEMAN	40 Clinton St., Brooklyn, N. Y.		May 4, 1897
STEVENS, PERLEY EGBERT	Care of Union Bridge Co., Athens, Pa.		April 6, 1897

CHANGES AND CORRECTIONS.

MEMBERS.

BASSEL, ROBERT	Royal Govt. Council of Const., Nicolausberger Weg 23, Göttingen, Germany.
BECKLER, ELBRIDGE HARLOW	Bardwell, Ky.
BLAKESLEE, CLARENCE	598 George St., New Haven, Conn.
BREITHAUPT, WILLIAM HENRY	35 Nassau St., New York City.
BROWN, CHARLES CARROLL	Cons. Engr., Bloomington, Ill.
BUTLER, MATTHEW JOSEPH	Chf. Engr., B. of Q. Ry., Napanee, Ontario, Canada.
CALKINS, FRANK AUGUSTUS	716 Warren Ave., Chicago, Ill.
CUSHING, EDWARD BENJAMIN	Gen. Supt. H. E. & W. T. Ry. and H. & S. Ry., Houston, Texas.
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Sewer Flushing Diagrams; Showing how far the Discharge from a Flush Tank will give a Self-Cleansing Velocity.

From Percy Allen, Sydney, N. S. W.:
Lift Bridge over the Murray at Swan Hill.

From Board of Railroad Commissioners, Albany, N. Y.:
Fourteenth Annual Report for the Fiscal year ending June 30th, 1896.

From Board of Trustees of the Sanitary District of Chicago, Chicago, Ill.:
Proceedings, March 3d, 9th and 10th, 17th, 24th, 25th, and 31st, 1897.

From Boston Society of Civil Engineers, Boston, Mass.:
The Library and the System of Cataloguing. Report of the Committee on the Library, March 17th, 1897.

From George Bowers, Lowell, Mass.:
Twenty-fourth Annual Report of the Lowell Water Board for 1896.

From California State Mining Bureau, Sacramento, Cal.:
Oil and Gas Yielding Formations of Los Angeles, Ventura, and Santa Barbara Counties, Part 1.

From Engineering Association of New South Wales, Sydney, N. S. W.
Minutes of Proceedings, Vol. IX, 1893-94.

From Engineers' Club of St. Louis, St. Louis, Mo.:
Bulletin, January, 1897, with List of Members.

From A. Fteley, New York, N. Y.:
Report of the Passaic Valley Sewerage Commission upon the General System of Sewage Disposal for the Valley of the Passaic River and Prevention of the Pollution thereof.

From James H. Fuertes, New York, N. Y.:
Some of the Important Water Supplies of Europe, Considered Mainly from a Sanitary Standpoint.

From Theodor G. Hoech, Washington, D.C,:
Ausschuss zur Untersuchung der Wasserverhaltnisse in den der Ueberschwemmungsgefahr besonders ausgesetzten Flussgebieten.

From J. W. Howard, New York, N. Y.:
Advantages of Good Pavements and Attractive Streets.

From Institution of Civil Engineers, London, Eng :
List of Members April 1st, 1897.
Minutes of Proceedings, Vol. CXXVII.

From Wellington B. Lee, Hillburn, N. Y.:
Switches and Frogs, Ramapo Iron Works.

From Massachusetts State Board of Health, Boston, Mass :
Report of the State Board of Health upon the Sanitary Condition of the Neponset Meadows, in the Towns of Canton, Sharon, Norwood, Dedham, Milton and Hyde Park.

From Charles Mayne, Shanghai, China:
Report of the Municipal Council of Shanghai for the year ended 31st December, 1896.

From Metropolitan Water Board, Boston, Mass.:
Second Annual Report, January 1, 1897.

From New York Meteorological Observatory, Central Park, N. Y.:
Meteorological Report for 1897.

From Passaic Valley Sewerage Commission, Newark, N. J.:
Report upon the General System of Sewerage Disposal for the Valley of the Passaic River and Prevention of the Pollution thereof, February, 1897.

From Patent Office, London, Eng.:
Abridgments of Specifications of Patents for Inventions, Heating, Hydraulic Machinery and Apparatus; Roads and Ways; Rotary Engines, Pumps, etc ; Signaling and Indicating by Signals; Medicine, Surgery and Dentistry; Table Articles and Appliances; Trunks, Portmanteaus, Hand and Like Traveling Bags, etc.

From Public Works Department, Calcutta, India:
Administration Report on the Railways in India for 1895-96.

From School of Practical Science, Toronto, Can.:
Papers read before the Engineering Society.

From J. Herbert Shedd, Providence, R. I.:
Annual Report of the City Engineer of the City of Providence for the year 1896.

From U. S. Department of Agriculture. Division of Forestry:
Summary of Mechanical Tests on Thirty-two Species of American Woods.

From U. S. Department of State:
Review of the World's Commerce. Introductory to Commercial Relations of the United States with Foreign Countries during the years 1895-1896.

From U. S. Geological Survey:
Thirty Maps of the Survey.

From U. S. Navy Department:
Register of the Commissioned and Warrant Officers of the Navy of the United States and of the Marine Corps to January 1, 1897. Notes on Naval Progress, January, 1897.

From U. S. War Department Chief of Engineers:
Seventeen Specifications for the Improvement of Certain Rivers and Harbors. Annual Report of the Secretary of War for the year 1896.

From University of the State of New York, Albany, N. Y.:
State Library Bulletin, Legislation No. 8, March, 1897. State Finance Statistics, 1890 and 1895.

From Western Society of Engineers, Chicago, Ill.:
Constitution, By-Laws and List of Members, June, 1896.

From E. D. Worcester, Secretary, New York, N. Y.:
Twenty-seventh Annual Report of the Lake Shore, and Michigan Southern Railway Company, 1896. Report of the Michigan Central Railroad Company for the year ending December 31st, 1896.

From Chas. H. Wright, Wilmington, Del., and Chas. B. Wing, Stamford University, California:
A Manual of Bridge Drafting.

From Chas. B. Wing, Stamford University, California:
Freehand Lettering for Working Drawings.

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INSTITUTED 1852.

PAPERS.

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CONTENTS:

THE DISTORTION OF RIVETED PIPE BY BACK-FILLING.

BY D. D. CLARKE, M. Am. Soc. C. E.

TO BE PRESENTED JUNE 2D, 1897.

During the years 1893 and 1894 there was constructed by the Water Committee of the City of Portland, Ore., and under the immediate supervision of the author as principal assistant engineer, a conduit 30 miles in length, for the purpose of bringing, for the supply of the city, the waters of Bull Run River, a beautiful mountain stream having its source a few miles distant from the base of Mt. Hood.

For 24 miles of the distance the conduit consists of a riveted steel pipe, the several sections of which are 33, 35 and 42 ins. in diameter.

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meetings, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

For the 42-in. pipe the plate varied in thickness from No. 6, B. W. G., to $\frac{3}{8}$ in., or 0.22 to 0.375 in. The 33-in. and 35-in. sections were made of No. 6 plate, B. W. G.*

The specifications for the manufacture of the plate called for steel having a tensile strength of 55 000 to 65 000 lbs. per square inch, with an elastic limit of 30 000 lbs. per square inch, and capable of being bent 180° when cold and hammered down flat without sign of fracture. The record of tests made during the process of manufacture shows that the plate was fully up to the standard for tensile strength and elasticity. The pipe trench was excavated chiefly in a clayey soil, but in a few places cement-gravel and boulders were encountered. The average depth of the trench was from 7 to 8 ft., but for short distances the depth was sometimes as great as 11 ft.

In January, 1894, while some of the employees of the contractors were at work inside a section of the 35-in. pipe, they discovered that the top of the pipe had been flattened, apparently by the weight of the earth covering. This having been brought to the attention of the author, he at once caused an examination to be made, with a view of determining the extent of the flattening of the pipe and its probable cause.

At that time there had been laid 8 miles of 35-in. pipe and about 1 mile of 42-in. pipe of No. 6 plate.

Measurements of the inside diameter of the pipe then laid were made at various points, particularly where the trench had been the deepest, and it was found that the crown of the pipe had been flattened quite generally, the amount of such flattening varying from $\frac{1}{2}$ in. to a maximum of 4 ins.

As the greatest depression was not found uniformly at the points where the pipe was buried the deepest, the conclusion seemed unavoidable that the earth had not been properly tamped around the pipe when the back-filling of the trench was being done. From this examination it also appeared probable that the top of the pipe had been flattened to a greater or less degree throughout its entire length, and the question therefore arose at once as to the effect, if any, which this distortion might have upon the calking of the seams.

Having reported to the chief engineer, Isaac W. Smith, M. Am. Soc. C. E., since deceased, the action that had so far been taken and

* See *Transactions*, Vol. xxxvi, p. 197.

the discoveries resulting therefrom, he immediately directed the author to make a series of experiments with the view of ascertaining if the pipe had been injured in any way by the changes in its shape which had been noticed. This step was taken in order to be prepared for any possible claim which might arise in the final settlement with the contractors.

In conducting these tests the design was to reproduce as nearly as possible the conditions under which the pipe had so far been laid, as to depth of trench, weight of covering, etc. With this end in view a plank box was constructed 20 ft. long, 8 ft. high, and having a top and bottom width to correspond to the average dimensions of the trench, $4\frac{1}{2}$ ft. at the bottom and $5\frac{1}{2}$ ft. at the top (Fig. 1). In this box was placed a section of the pipe 29 ft. 3 ins. long, the usual length of the sections as they came from the shop. Each section consisted of alternate large and small plates, six in all. The box was then filled with coarse sand, weighing about 80 lbs. per cubic foot. The sand was carefully packed around and over the pipe for a distance of 20 ft. along its central portion, the pipe projecting about 5 ft. at each end of the box.

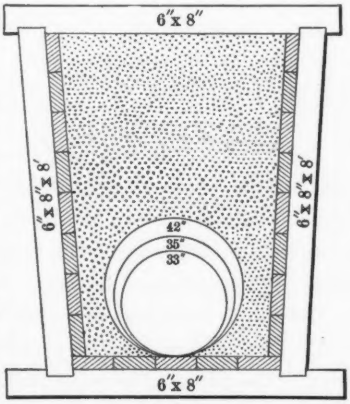

FIG. 1.

Test No. 1.—This was made with a section of the 33-in. pipe of No. 6 plate. The sand was carefully tamped to a height of $5\frac{2}{3}$ ft. above the top of the pipe. The approximate weight was 460 lbs. per square foot. The vertical and horizontal diameters on the inside of the small courses were carefully measured at the center and at a point 10 ft. on each side of the center, or 5 ft. from each end of the pipe. These measurements were taken before the pipe was covered, and again after it had been standing covered for forty hours, when it was found that the top of the pipe had been depressed $\frac{3}{8}$ in. After removing the sand from the box, the pipe was again measured and found to have regained its original form.

Test No. 2.—The pipe used in Test 1 was covered with sand loosely piled to a depth of 3 ft. above the top of the pipe. This load caused

a depression of $\frac{3}{16}$ in. The pipe was then covered to a depth of $5\frac{2}{3}$ ft., which depressed the top between $\frac{1}{4}$ and $\frac{5}{16}$ in. Upon removing the load, the pipe came back to its original dimensions.

Test No. 3.—The 33-in. pipe used in Tests 1 and 2 was next braced on the outside with timbers wedged against the sides of the box. These timbers were placed at the center and at points about midway between the center and each end of the pipe, and were wedged in so as to compress the sides of the pipe slightly. Upon filling the box with loose sand a depression of the top of the pipe was noticed, varying from $\frac{3}{8}$ to $\frac{7}{16}$ in., showing that a thorough tamping of sand around the pipe made a better support than the timber braces. Upon uncovering the pipe and removing the braces, the pipe regained its former vertical diameter within $\frac{1}{16}$ in.

This concluded the tests of the 33-in. pipe. The loads applied were equal to the average weight of the pipe covering in the trench, and, upon removing them, the pipe practically regained its original form in each instance.

Test No. 4.—This was made with a section of 42-in. pipe, No. 4 plate. This pipe was placed in the box and covered with carefully tamped sand to a depth of $5\frac{1}{4}$ ft. After standing fifteen hours the measurements taken showed a vertical compression varying from $\frac{3}{8}$ to $\frac{7}{16}$ in. When unloaded the pipe regained its original form.

Test No. 5.—For this test a section of 42-in. pipe of No. 6 plate was used. The sand was tamped solidly to a height of $5\frac{1}{4}$ ft. above the crown of the pipe. The estimated weight was 420 lbs. per square foot. This caused a depression of the top varying from $\frac{7}{16}$ to $\frac{9}{16}$ in. Upon removing the load, the pipe regained its former diameter.

Test No. 6.—The same pipe used in Test 5 was then supported on the sides by timbers placed $7\frac{1}{2}$ ft. centers and wedged against the sides of the box. The pipe was next covered with sand, thoroughly tamped as in Test 5, and in addition some iron castings were distributed along the center of the pipe on top of the sand, making a total load of 520 lbs. per square foot, equal to that of a fill of $6\frac{1}{2}$ ft. above the top of the pipe. This load depressed the top of the pipe $\frac{7}{16}$ in. When the load and braces were removed, the pipe regained its former vertical dimensions, with a variation of $\frac{1}{8}$ in. at one point only.

Test No. 7.—In order to show the effect of more severe treatment, the section of pipe used in Test 6 was again placed in position, and a

timber platform placed on top of it and loaded with iron castings, the sides of the pipe not being supported in any manner. A load weighing 17 600 lbs. was then applied, which caused a maximum compression of $1\frac{5}{8}$ ins.; upon removing the load, the pipe regained its former vertical diameter within $\frac{1}{4}$ in.

The pipe was then removed from the box and subjected to an internal hydrostatic pressure of 150 lbs. per square inch, but no leaks appeared.

Test No. 8.—The pipe used in Test 7 was again placed in position without support for the sides, and the top was loaded with a box filled with sand weighing 36 000 lbs. After supporting this load for 40 hours, measurements of the vertical diameter showed a compression ranging from $3\frac{1}{2}$ to $4\frac{9}{16}$ ins. Removing the load, the pipe regained its former vertical diameter within $\frac{3}{8}$ in.

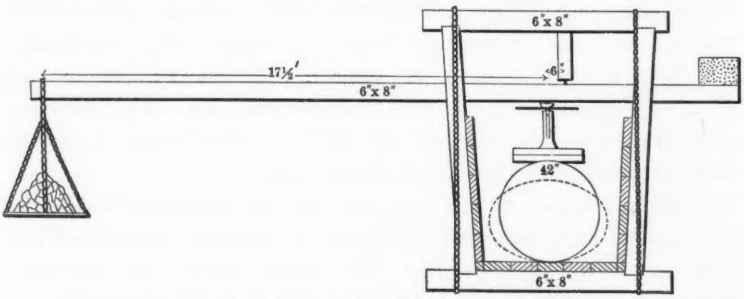

FIG. 2.

Test No. 9.—The pipe used in Test 8 was covered with sand, thoroughly tamped, to a depth of $5\frac{1}{4}$ ft. on the top of the pipe, and the sand saturated with water. This caused a depression of the top varying from $\frac{3}{4}$ to 1 in., the pipe regaining its former dimensions upon removing the load. The pipe was again subjected to 150 lbs. per square inch hydrostatic pressure, but no leaks appeared.

Test No. 10.—As a final test the pipe section used in Tests 5 to 9, inclusive, was again placed in position, and by means of three jack screws, placed one at the center and one 5 ft. from each end, the pipe was compressed $8\frac{3}{16}$, $8\frac{11}{16}$ and $8\frac{3}{4}$ ins. at the several points. By an arrangement of levers (Fig. 2), the pressure required to produce this effect was found to be 13 390, 14 190 and 15 170 lbs., or a total of 42 750 lbs. A final test to 150 lbs. per square inch hydrostatic pressure failed to discover any leak in the pipe. Measurements taken after the pipe

was removed from the hydrostatic press showed a permanent set of $1\frac{1}{8}$ and $1\frac{5}{8}$ ins.

No further tests of the pipe were made, nor were they considered necessary, it having been shown by those already made that the conditions under which the pipe had been laid had not been injurious.

The conclusion reached at the time, as the result of the foregoing tests, was that some degree of compression of the pipe might be expected with all sizes and weights of plate in use on the line; that this compression could not be entirely avoided without considerably increasing the cost of the work; and that if this compression did exist, it would not injure the pipe.

When the work of pipe laying was resumed in the spring of 1894, additional inspectors were employed, and the work of back-filling was closely watched for the purpose of securing a strict compliance with the specifications, which provided that below the upper surface of the pipe the earth must be tamped in layers not exceeding 6 ins. in thickness.

In order to have some further practical evidence as to the cost and effect of properly doing the work of back-filling, a point on the 42-in. pipe laid the previous year was selected where a flattening of the top varying from $1\frac{5}{8}$ to $2\frac{3}{4}$ ins. was known to exist.

One hundred feet of this pipe was then uncovered, the inside diameter of the small courses being carefully measured, both before and after the earth was removed. The record shows that the pipe expanded vertically from $\frac{1}{4}$ to $1\frac{5}{8}$ ins. as soon as it was uncovered.

The earth from the trench, principally yellowish clay and sand, was then carefully tamped around and over the pipe. Below the top of the pipe one man used a tamping bar for each man with a shovel. For the remainder of the trench, one tamping bar was used to three shovels. The cost of back-filling for this short section was 9 cents per cubic yard of the original trench excavation. Measurements taken when the pipe had been covered again, showed a vertical compression of but $\frac{1}{8}$ in. during the process of refilling and tamping.

In this connection mention may be made of a point on the 35-in. pipe where the flattening of the top was found to reach a maximum of 3 ins. when measured in February, 1894. During an inspection of the pipe line in June, 1896, this section was measured again and the flattening was found to be from $\frac{1}{2}$ in. to 2 ins. The trench was excavated in sandy clay soil, the pipe covering ranging from 4 to 5 ft. in depth.

When the last measurement was taken, the pipe had been subjected to a hydraulic pressure of 60 lbs. per square inch for sixteen months.

The foregoing notes are presented with the thought that possibly they may be of service to some seeker after light upon the question of the depth of trench permissible for steel water pipe under certain conditions. Such information was not available to the author at the time the grades for the Bull Run pipe line were decided upon. At one summit a cut of from 12 to 16 ft. was required for a distance of 1 500 ft. Under the circumstances it was necessary that the trench should be entirely refilled, and, in order to avoid an excessive loading of the pipe, an expense of $1 500 was incurred in grading off the entire width of the right-of-way road, so that the pipe covering would not exceed a maximum depth of 7 ft. This would not be done again under similar circumstances.

A detailed statement of measurements taken appears in the following tables :

RIVETED STEEL PIPE ; 29 FT. 3 INS. LONG, 33 INS. DIAMETER, No. 6 PLATE, B. W. G.

TEST No. 1.

	5 FT. FROM END.		CENTER.		5 FT. FROM END.	
	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.
Pipe in place, unloaded	......	......	$32\frac{3}{4}''$	$32\frac{11}{16}''$	......	......
Sand tamped around pipe, $5\frac{3}{4}$ ft. deep on top	$32\frac{3}{4}''$	$33''$	$32\frac{3}{8}''$	$33\frac{1}{4}''$	$32\frac{9}{16}''$	$33\frac{3}{16}''$
After standing 40 hours	$32\frac{3}{4}''$	$33\frac{1}{8}''$	$32\frac{3}{8}''$	$33\frac{3}{8}''$	$32\frac{9}{16}''$	$33\frac{1}{4}''$
Compression	......	......	$\frac{3}{8}''$	......	......	......
Pipe unloaded	$33''$	$32\frac{7}{8}''$	$32\frac{3}{4}''$	$33''$	$32\frac{7}{8}''$	$33''$
Expansion	......	......	$\frac{3}{8}''$	......	......	......

TEST No. 2.

Pipe unloaded	$33''$	$32\frac{7}{8}''$	$32\frac{3}{4}''$	$33''$	$32\frac{7}{8}''$	$33''$
Sand $5\frac{3}{4}$ ft. deep, loosely piled	$32\frac{11}{16}''$	$33\frac{1}{8}''$	$32\frac{3}{8}''$	$33\frac{7}{16}''$	$32\frac{5}{8}''$	$33\frac{1}{4}''$
Compression	$\frac{5}{16}''$	......	$\frac{3}{8}''$	......	$\frac{1}{4}''$	......
Pipe unloaded	$33''$	$32\frac{13}{16}''$	$32\frac{3}{4}''$	$33''$	$32\frac{7}{8}''$	$32\frac{15}{16}''$
Expansion	$\frac{5}{16}''$	......	$\frac{3}{8}''$	......	$\frac{1}{4}''$	......

TEST No. 3.

Pipe unloaded and braced outside	$33\frac{1}{8}''$	$32\frac{5}{8}''$	$32\frac{7}{8}''$	$32\frac{13}{16}''$	$32\frac{15}{16}''$	$32\frac{13}{16}''$
Pipe loaded, sand $5\frac{3}{4}$ ft. deep	$32\frac{3}{4}''$	$33''$	$32\frac{7}{16}''$	$33\frac{1}{4}''$	$32\frac{5}{8}''$	$33\frac{3}{16}''$
Compression	$\frac{3}{8}''$	......	$\frac{7}{16}''$	......	$\frac{5}{16}''$	......
Pipe unloaded	$33\frac{1}{16}''$	$32\frac{3}{4}''$	$32\frac{3}{4}''$	$33''$	$32\frac{7}{8}''$	$32\frac{7}{8}''$
Expansion	$\frac{5}{16}''$	......	$\frac{3}{8}''$	......	$\frac{5}{16}''$	......

Riveted Steel Pipe, 29 Ft. 3 Ins. Long, 42 Ins. Diameter, No. 4 Plate, B. W. G.

Test No. 4.

	Small Plate End.		5 Ft. from End.		Center.		5 Ft. from End.		Large Plate End.	
	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.
Pipe in place, unloaded.	41½"	42¼"	41 7/16"	42⅜"	41 9/16"	42 3/16"	41¼"	42½"	41 13/16"	42 13/16"
Sand tamped around pipe, 5¼ ft. deep on top	41¼"	42½"	41 1/16"	42 11/16"	41 3/16"	42⅝"	40 13/16"	42⅞"	41½"	43 3/16"
Compression	¼"	......	⅜"	......	⅜"	......	7/16"	.....	5/16"	
Pipe unloaded	41½"	42¼"	41 7/16"	42 7/16"	41⅝"	42 3/16"	41¼"	42½"	41¾"	42 13/16"
Expansion	¼"	......	⅜"	......	7/16"	......	7/16"	.....	¼"	

Test No. 5, 42-In. Pipe, No. 6 Plate, B. W. G.

Pipe in place, unloaded.	41⅜"	42⅜"	41 7/16"	42 5/16"	41 11/16"	42⅛"	41¼"	42½"	41⅞"	42 11/16"
Sand tamped around pipe, 5¼ ft. deep on top	40 15/16"	42 13/16"	40⅞"	42¾"	41 3/16"	42⅝"	40 11/16"	43"	41⅜"	43 3/16"
Compression	7/16"	......	9/16"	......	¾"	......	9/16"	......	½"	
Pipe unloaded	41⅜"	42 5/16"	41½"	42 3/16"	41¾"	42 1/16"	41⅜"	42 7/16"	41⅞"	42⅝"
Expansion	7/16"	......	⅝"	......	9/16"	......	11/16"	......	½"	

Test No. 6.

Pipe unloaded, braced outside, 7½ ft. centers	41¾"	42 1/16"	41 15/16"	41 13/16"	42 5/16"	41¼"	41⅞"	41⅛"	42⅜"	42¼"
Sand tamped around pipe load	41⅝"	42⅜"	41½"	42 3/16"	41⅞"	41¼"	41 7/16"	42¼"	42 1/16"	42½"
Compression	7/16"	.....	7/16"	......	7/16"	......	7/16"	......	5/16"	
Pipe unloaded and braces removed	41⅜"	42⅜"	41½"	42¼"	41¾"	42 1/16"	41⅜"	42⅜"	42"	42⅝"
Expansion	1/16"	......	0							

Test No. 7.

Pipe in place, unloaded.	41⅜"	42⅜"	41½"	42¼"	41¾"	42 1/16"	41⅜"	42⅜"	42"	42⅝"
Platform loaded with 4 800 lbs. iron placed on top of pipe. Sides unsupported	40 15/16"	42¾"	40 15/16"	42 11/16"	41 3/16"	42½"	40¾"	42 15/16"	41⅜"	43⅛"
Weight increased to 17 000 lbs	40 5/16"	43⅜"	40 3/16"	43½"	40 3/16"	43⅝"	39¾"	43 15/16"	40 7/16"	44"
Compression	1 1/16"	......	1 5/16"	......	1 9/16"	......	1⅝"	......	1 9/16"	
Pipe unloaded	41⅜"	42⅜"	41 7/16"	42 5/16"	41⅝"	42⅛"	41¼"	42½"	41 13/16"	42¾"
Expansion	1 1/16"	......	1¼"	......	1 7/16"	......	1½"	......	1⅜"	

Pipe subjected to hydrostatic pressure of 150 lbs. per square inch. No leaks found.

TEST NO. 8, 42-IN. PIPE, NO. 6 PLATE, B. W. G.—(*Continued*).

	SMALL PLATE END.		5 FT. FROM END.		CENTER.		5 FT. FROM END.		LARGE PLATE END.	
	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.
Pipe in place, unloaded.	$41\frac{5}{16}''$	$42\frac{3}{8}''$	$41\frac{7}{16}''$	$42\frac{1}{4}''$	$41\frac{11}{16}''$	$42\frac{1}{8}''$	$41\frac{1}{4}''$	$42\frac{1}{2}''$	$41\frac{7}{8}''$	$42\frac{11}{16}''$
Box filled with sand, weight, 36 000 lbs. placed on top of pipe. Sides unsupported...	$38\frac{11}{16}''$	$44\frac{3}{4}''$	$38\frac{1}{16}''$	$45\frac{1}{8}''$	$37\frac{9}{16}''$	$45\frac{13}{16}''$	$37\frac{11}{16}''$	$46\frac{3}{8}''$	$37\frac{1}{2}''$	$46\frac{1}{2}''$
After standing 40 hours	$38\frac{11}{16}''$	$44\frac{13}{16}''$	$37\frac{15}{16}''$	$45\frac{1}{8}''$	$37\frac{1}{2}''$	$45\frac{7}{8}''$	$36\frac{9}{16}''$	$46\frac{1}{8}''$	$37\frac{3}{8}''$	$46\frac{9}{16}''$
Compression.....	$2\frac{5}{8}''$	......	$3\frac{1}{2}''$	......	$4\frac{3}{16}''$	......	$4\frac{9}{16}''$	......	$4\frac{1}{2}''$	
Pipe unloaded.........	$41\frac{9}{16}''$	$42\frac{9}{16}''$	$41\frac{3}{16}''$	$42\frac{7}{16}''$	$41\frac{7}{16}''$	$42\frac{3}{8}''$	$41''$	$42\frac{13}{16}''$	$41\frac{1}{2}''$	$42\frac{15}{16}''$
Expansion.............	$2\frac{1}{8}''$	......	$3\frac{1}{4}''$	......	$3\frac{15}{16}''$	......	$4\frac{7}{16}''$	......	$4\frac{1}{8}''$	
Apparent set.....	$\frac{1}{8}''$	......	$\frac{1}{4}''$	......	$\frac{1}{4}''$	......	$\frac{1}{8}''$	......	$\frac{3}{8}''$	

TEST NO. 9.

Pipe in place, unloaded.	$41\frac{3}{16}''$	$42\frac{9}{16}''$	$41\frac{3}{16}''$	$42\frac{7}{16}''$	$41\frac{7}{16}''$	$42\frac{3}{8}''$	$41''$	$42\frac{13}{16}''$	$41\frac{1}{2}''$	$42\frac{15}{16}''$
Sand tamped around pipe $5\frac{1}{4}$ ft. deep on top	$40\frac{11}{16}''$	$43''$	$40\frac{1}{2}''$	$43''$	$40\frac{3}{4}$	$43\frac{1}{16}''$	$40\frac{1}{4}''$	$43\frac{3}{8}''$	$40\frac{15}{16}''$	$43\frac{1}{2}''$
Sand saturated with water	$40\frac{7}{16}''$	$43\frac{1}{4}''$	$40\frac{1}{4}''$	$43\frac{3}{16}''$	$40\frac{1}{2}''$	$43\frac{1}{4}''$	$40''$	$43\frac{9}{16}''$	$40\frac{11}{16}''$	$43\frac{3}{4}''$
Compression...........	$\frac{3}{4}''$	......	$\frac{15}{16}''$	......	$\frac{15}{16}''$	......	$1''$	......	$\frac{13}{16}''$	
Pipe unloaded.........	$41\frac{3}{16}''$	$42\frac{1}{2}''$	$41\frac{3}{16}''$	$42\frac{7}{16}''$	$41\frac{1}{2}''$	$42\frac{3}{8}''$	$41''$	$42\frac{3}{4}''$	$41\frac{9}{16}''$	$42\frac{7}{8}''$
Expansion.............	$\frac{3}{4}''$	......	$\frac{15}{16}''$	......	$1''$	......	$1''$	......	$\frac{7}{8}''$	

Pipe subjected to hydrostatic pressure of 150 lbs. per square inch. No leaks found.

TEST NO. 10.

Pipe in place, unloaded...............	$41\frac{1}{4}''$	$42\frac{7}{16}''$	$41\frac{1}{4}''$	$42\frac{3}{8}''$	$41\frac{1}{2}''$	$42\frac{5}{16}''$	$41''$	$42\frac{3}{4}''$	$41\frac{9}{16}''$	$42\frac{15}{16}''$
Estimated weights applied by means of jack screws at points 1, 2 and 3.............	......	......	13 390	lbs.	14 190	lbs.	15 170	lbs		
Pipe then measured...	$33\frac{3}{4}''$	$48\frac{7}{8}''$	$33\frac{1}{16}''$	$48\frac{1}{4}''$	$32\frac{13}{16}''$	$48\frac{15}{16}''$	$32\frac{1}{4}''$	$49\frac{15}{16}''$	$33\frac{1}{16}''$	$49\frac{13}{16}''$
Compression	$7\frac{1}{2}''$	......	$8\frac{3}{16}''$	......	$8\frac{11}{16}''$	......	$8\frac{3}{4}''$	......	$8\frac{1}{2}''$	
Pipe unloaded after 24 hours...............	$38\frac{7}{16}''$	$45\frac{3}{16}''$	$38\frac{5}{8}''$	$45\frac{1}{4}''$	$38\frac{13}{16}''$	$45\frac{3}{8}''$	$38\frac{7}{16}''$	$45\frac{7}{16}''$	$38\frac{3}{4}''$	$45\frac{1}{2}''$
Expansion......	$4\frac{11}{16}''$	......	$5\frac{9}{16}''$	......	$6''$	......	$6\frac{3}{16}''$	......	$5\frac{11}{16}''$	
Apparent set..........	$2\frac{13}{16}''$	......	$2\frac{5}{8}''$	......	$2\frac{11}{16}''$	......	$2\frac{9}{16}''$	......	$2\frac{13}{16}''$	

Pipe subjected to hydrostatic pressure of 150 lbs per square inch. No leaks found.

After removing from hydrostatic pressure.	$39\frac{9}{16}''$	$44''$	$39\frac{3}{4}''$	$44\frac{1}{4}''$	$39\frac{7}{8}''$	$44\frac{5}{16}''$	$39\frac{1}{2}''$	$44\frac{1}{2}''$	$39\frac{7}{8}''$	$44\frac{1}{2}''$
Permanent set.........	$1\frac{13}{16}''$	......	$1\frac{11}{16}''$	......	$1\frac{13}{16}''$	......	$1\frac{3}{4}''$	......	$2''$	

MEASUREMENTS OF 42-IN. PIPE, NO. 6 PLATE, IN TRENCH.

	COVERED.		UNCOVERED		AGAIN COVERED.	
	Vert.	Hor.	Vert.	Hor.	Vert.	Hor.
Station 1 320 + 20	39¾″	43⅜″	40″	44″	40″	44″
" " + 30	40⅛″	43¾″	41″	43⅛″	40⅞″	43¼″
" " + 40	39¾″	43⅝″	41⅛″	42⅝″	41″	42¾″
" " + 50	40⅛″	43¾″	41⅜″	42¾″	41¼″	42⅞″
" " + 60	39¼″	44⅜″	40⅞″	43⅛″	40¾″	43¼″
" " + 70	39⅝″	43¾″	41⅛″	42¾″	41″	42⅞″
" " + 80	39⅞″	43⅝″	41⅛″	42¾″	41″	42⅞″
" " + 90	40⅜″	43⅛″	41⅛″	42½″	41⅛″	42⅞″
" 1 321 + 00	39¾″	44″	41″	43″	40⅞″	43⅛″
" " + 10	40⅛″	43½″	40⅜″	43¼″	40¼″	43¼″
" " + 20	39½″	43¼″	40⅞″	43″	40⅞″	43″

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THE RELATION OF TENSILE STRENGTH TO COMPOSITION IN STRUCTURAL STEEL.

BY A. C. CUNNINGHAM, M. Am. Soc. C. E.

TO BE PRESENTED AT THE ANNUAL CONVENTION, 1897.

Rule.—To find the approximate tensile strength of structural steel to a base of 40 000 lbs., add 1 000 lbs. for every 0.01% of carbon, and 1 000 lbs. for every 0.01% of phosphorus, neglecting all other elements in normal steels. Radical variations between calculated and actual strength indicate mixed steels, segregation, incorrect analyses, or unusual treatment in manufacture.

The relation of composition to tensile strength in steel has been a matter of interest, speculation and investigation since the time that it has been analyzed and tested. It has long been known that steel of about 1% carbon, or 100 carbon, as it is generally called, possesses the greatest tensile strength, and that as the carbon increases or decreases from this point, there is a decrease of tensile strength. This fact is of more interest than value to the structural engineer, who cannot make use of such hard steel as this for tension members. It has also been assumed that all other elements besides carbon entering into the com-

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position of steel gave more or less strengthening effect; some were supposed to be slight, others great, and it is known in the case of manganese that radical changes take place in the nature of steel as the percentage of this element reaches certain amounts.

Years of experience have taught that carbon is the most desirable element for giving strength to steel; that definite results can be produced by varying its amount, and that the gain of strength due to its increase is accompanied with less loss of other desirable properties than is the case with any other hardener. All other elements occurring in carbon steels may be considered impurities or antidotes.

In investigating the causes of strength in steel, one naturally looks first for the strength of its base of iron and at once encounters an unknown quantity. Pure iron can be produced only in the laboratory, and even there in insufficient quantity and impossible condition for testing. The strength of pure iron has, however, been estimated and calculated to be about 38 000 lbs. per square inch.

The most notable investigations made of late years into the strengthening effects of the different elements occurring in steel have been made by Mr. Wm. R. Webster, and H. H. Campbell, M. Am. Soc. C. E., in the order named.

Mr. Webster's investigations were made upon plates of basic Bessemer steel, and consisted of assumptions subjected to trial, and variously modified to suit the conditions. He believed that all elements had a strengthening effect upon steel, and constructed tables from which, knowing the carbon, phosphorus, manganese and sulphur content of steel, its tensile strength could be calculated. His tables fitted very well the steel upon which he made his investigations, but have not proved satisfactory in the case of other steels.

The later investigations of Mr. Campbell are the most complete and scientific of any that have yet been undertaken in this line. With 3 163 tests made upon 2 x $\frac{3}{8}$-in. test bars of a known and uniform condition, arranged in 272 groups of similar conditions as to strength and composition, Mr. Campbell has, by the method of least squares, arrived at the strengthening effect of the various components of steel.*

* Mr. Campbell's work will be found in full in his book on "The Manufacture and Properties of Structural Steel."

Tables Nos. 1 and 2 at the close of the paper give one-fifth of his tests, and a comparison between them and the strength of the metal as computed by his formula and those of Mr. Webster and the author. The same data for all the 272 groups were calculated by the author, and are on file in the Library of the Society; they show the same comparative relations between actual and calculated strengths as the abridged tables.

Mr. Campbell's conclusions are as follows:

First.—The strength of pure iron, as far as it can be determined from the strength of steel, is about 38 000 or 39 000 lbs. per square inch.

Second.—An increase of 0.01% of carbon raises the tensile strength of acid steel about 1 210 lbs. per square inch, and that of basic steel about 950 lbs.

Third.—An increase of 0.01% of manganese has very little effect on acid steel, unless the content exceeds 0.60%, but it raises the strength of basic steel about 85 lbs. per square inch.

Fourth.—An increase of 0.01% of phosphorus raises the tensile strength of acid steel about 890 lbs. per square inch, and that of basic steel about 1 050 lbs.

Fifth.—The following formulas will give the ultimate strength of ordinary open-hearth steel in pounds per square inch, the carbon, manganese and phosphorus being expressed in units of 0.001%, and a value being given to R in accordance with the conditions of rolling and the thickness of the pièce.

Formula for Acid Steel:

$$38\,600 + 121 \text{ carbon} + 89 \text{ phos.} + R = \text{tensile strength.}$$

Formula for Basic Steel:

$$37\,430 + 95 \text{ carbon} + 8.5 \text{ mang.} + 105 \text{ phos.} + R = \text{tensile strength.}$$

Sixth.—The metals from which these data were derived were ordinary structural steels ranging from 0.02 to 0.35% of carbon, and it is not expected that the formulas are applicable to higher steels or to special alloys.

Seventh.—A considerable difference may be found between steels which apparently are of the same composition, and which, as far as known, have been made under the same conditions.

Eighth.—In the case of acid steel, an increase in manganese above 0.6% will raise the tensile strength above the amount indicated by the formula, the increment being quite marked when a content of 0.8 is exceeded.

Ninth.—In steels containing from 0.3% to 0.5% of carbon, the value of the metalloids is fully as great as with the lower steels, while the presence of silicon in such metal in proportions greater than 0.15% seems to enhance the strengthening effect of carbon.

Tenth.—In steels containing less than 0.25% of carbon, the effect of small proportions of silicon upon the ultimate strength is inappreciable.

Eleventh.—Sulphur in ordinary proportions exerts no appreciable influence upon the tensile strength.

Twelfth.—Both acid and basic steels containing less than 0.3% of manganese give an actual strength greater than is shown by the formula, and when this is taken with the abnormal strength of unusually pure metal used in certain tests,* it is indicated that oxide of iron raises the ultimate strength.

Up to the present time the relation of tensile strength to composition has been, at the most, a matter of passing interest to the engineer. A test report showing 30 carbon and 58 000 lbs. tensile strength for one test, and 15 carbon and 60 000 lbs. for another might cause some wonderment on the part of the engineer who received it, but until recent times the chemist and his work has seldom been questioned.

The formulas deduced by Mr. Campbell offer a check on the analysis and the tensile test of steel. They are likely to prove of more value to the steel-maker than to the engineer, for they can not be retained in the memory of one having only an occasional use for them, and their application to a report of a hundred tests would be a tedious operation. A consideration of the work previously done in this line has led the author to the adoption of the rule given at the head of this paper for comparing analyses with tensile tests.

This rule is so simple that a few trials will permanently impress it on the memory. The operation may be made mentally with great rapidity, and, as far as tried, is equally applicable to all kinds and makes of steel.

* "See Manufacture and Properties of Structural Steel," Table No. 131, Group 198.

TABLE No. 1.—ACID OPEN-HEARTH STEEL.

Number of group.	Average Analysis. Percentage of.				Average actual ultimate pounds per square inch.	Campbell.		Webster.		Cunningham.	
	Carbon by combustion.	Phosphorus.	Manganese.	Sulphur.		Calculated ultimate pounds per square inch.	Difference.	Calculated ultimate pounds per square inch.	Difference.	Calculated ultimate pounds per square inch.	Difference.
1..	.061	.069	.29	.071	54 700	52 120	− 2 580	55 400	+ 700	53 000	− 1 700
6..	.087	.060	.33	.043	55 470	54 470	− 1 000	56 940	+ 1 470	54 700	− 770
11..	.096	.075	.25	.060	57 200	56 890	− 310	59 150	+ 2 260	57 100	− 100
16..	.117	.556	.39	.028	56 950	57 740	+ 790	60 790	+ 3 840	57 300	+ 350
21..	.125	.047	.41	.032	56 960	57 910	+ 950	61 340	+ 4 380	57 200	+ 240
26..	.130	.053	.40	.042	59 170	59 050	− 120	62 740	+ 3 570	58 300	− 870
31..	.143	.099	.39	.065	62 830	64 710	+ 1 880	71 640	+ 8 810	64 200	+ 1 370
36..	.155	.069	.41	.034	60 940	63 500	+ 2 560	67 690	+ 6 750	62 400	+ 1 460
41..	.170	.074	.43	.046	64 840	65 760	+ 920	70 920	+ 6 080	64 400	− 440
46..	.207	.088	.41	.047	69 410	71 480	+ 2 070	76 140	+ 6 739	69 500	+ 90
51..	.229	.065	.50	.032	70 810	72 090	+ 1 280	74 400	+ 3 590	69 400	− 1 410
56..	.424	.043	.57	.031	94 470	93 730	− 740	......	....	86 700	− 7 770
61..	.113	.061	.43	.038	57 140	57 700	+ 560	61 070	+ 3 830	57 400	+ 260
66..	.116	.082	.50	.069	60 870	59 930	− 940	67 300	+ 6 430	59 800	− 1 070
71..	.118	.075	.42	.045	59 110	59 550	+ 440	64 480	+ 5 370	59 300	+ 190
76..	.119	.065	.43	.028	61 020	58 780	− 2 240	62 570	+ 1 550	58 400	− 2 620
81..	.134	.045	.48	.035	58 820	58 820	0	62 410	+ 3 590	57 900	− 920
86..	.151	.051	.64	.033	62 650	61 410	− 1 240	67 200	+ 4 550	60 200	− 2 450
91..	.183	.027	.68	.030	65 100	63 150	− 1 950	66 100	+ 1 000	61 000	− 4 100
96..	.212	.073	.82	.039	71 870	70 750	− 1 120	82 230	+10 360	68 500	− 3 370
101..	.242	.076	.86	.049	78 020	74 650	− 3 370	85 690	+ 7 670	71 800	− 6 220
106..	.374	.057	.83	.035	90 750	88 930	− 1 820	......	....	83 100	− 7 650
111..	.392	.029	.63	.022	98 180	88 610	− 9 570	......	....	82 100	−16 080
116..	.333	.041	.65	.026	87 410	82 540	− 4 870	......	....	77 400	−10 010
121..	.480	.032	.69	.022	111 740	99 530	−12 210	......	....	91 200	−20 540
126..	.555	.109	1.13	.042	123 620	115 460	− 8 160	......	....	106 400	−17 220

TABLE No. 2.—Basic Open-Hearth Steel.

No. of group.	Average Analysis. Percentage of. Carbon by combustion.	Phosphorus.	Manganese.	Sulphur.	Average actual ultimate Pounds per square inch.	Campbell. Calculated ult. Pounds per square inch.	Campbell. Difference.	Webster. Calculated ult. Pounds per square inch.	Webster. Difference.	Cunningham. Calculated ult. Pounds per square inch.	Cunningham. Difference.
127..	.051	.008	.25	.027	46 630	45 240	− 1 390	......	....	45 900	− 730
132..	.070	.009	.36	.050	47 360	48 090	+ 730	51 610	+ 4 250	47 900	+ 540
137..	.074	.021	.38	.034	49 280	49 900	+ 620	52 730	+ 3 450	49 500	+ 220
142..	.082	.014	.43	.038	50 770	50 350	− 420	53 270	+ 2 500	49 600	− 1 170
147..	.105	.012	.53	.032	52 970	53 170	+ 200	56 450	+ 3 480	51 700	− 1 270
152..	.127	.010	.43	.019	52 980	54 200	+ 1 220	56 420	+ 3 440	53 700	+ 720
157..	.144	.013	.30	.037	55 260	55 030	− 230	56 800	+ 1 540	55 700	+ 440
162..	.165	.021	.41	.051	57 220	58 800	+ 1 580	62 640	+ 5 420	58 600	+ 1 380
167..	.170	.040	.42	.043	61 070	61 770	+ 700	65 630	+ 4 310	61 000	+ 70
172..	.183	.008	.36	.030	57 350	58 710	+ 1 360	60 110	+ 2 760	59 100	+ 1 750
177..	.194	.023	.51	.040	61 340	62 610	+ 1 270	65 700	+ 4 360	61 700	+ 360
182..	.209	.024	.47	.053	63 220	63 800	+ 580	67 490	+ 4 270	63 300	+ 80
187..	.220	.015	.40	.018	63 560	63 300	− 260	64 100	+ 540	63 500	+ 60
192..	.248	.018	.40	.033	66 220	66 280	+ 60	67 200	+ 980	66 600	+ 380
197..	.301	.017	.65	.029	76 890	73 340	− 3 550	......	....	71 800	+ 5 090
202..	.052	.019	.35	.054	49 010	47 340	− 1 670	......	....	47 100	+ 1 910
207..	.062	.015	.21	.036	48 980	46 680	− 2 300	47 570	− 1 410	47 700	− 1 280
212..	.076	.018	.41	.062	50 880	50 030	− 850	53 790	+ 2 910	49 400	− 1 480
217..	.084	.021	.25	.033	50 900	49 740	− 1 160	50 300	− 600	50 500	− 400
222..	.094	.046	.43	.036	54 800	54 840	+ 40	56 820	+ 2 020	54 000	− 800
227..	.103	.027	.44	.064	54 950	53 790	− 1 160	57 610	+ 2 660	53 000	− 1 950
232..	.117	.053	.46	.035	57 210	58 020	+ 810	62 120	+ 4 910	57 000	− 210
237..	.125	.036	.54	.060	58 790	57 680	− 1 110	63 000	+ 6 210	56 100	− 2 690
242..	.134	055	.51	.036	59 110	60 270	+ 1 160	64 100	+ 4 990	58 900	− 210
247..	.144	.028	.52	.034	58 970	58 470	− 500	61 950	+ 2 980	57 200	− 1 270
252..	.153	.012	.46	.027	58 970	57 130	− 1 840	59 020	+ 50	56 500	− 2 470
257..	.173	.021	.53	.021	60 810	60 570	− 240	62 600	+ 1 790	59 400	− 1 410
262..	.190	.047	.72	.037	66 480	66 530	+ 50	74 510	+ 7 930	63 700	− 2 780
267..	.215	.011	.42	.024	63 470	62 580	− 890	64 630	+ 1 160	62 600	− 870
272..	.338	.017	.62	.026	77 950	76 600	− 1 350	......	....	75 500	− 2 450

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RECENT TESTS OF BRIDGE MEMBERS.

By J. E. GREINER, M. Am. Soc. C. E.

TO BE PRESENTED AT THE ANNUAL CONVENTION, 1897.

During the past two years the author has made a number of tension tests on bridge members other than eye-bars. These tests, while not exhaustive, are in a channel outside of the usual run, and it is believed that the results obtained furnish information of a kind likely to be of general interest and value. The investigations are divided into six series, *A*, *B*, *C*, *D*, *E* and *F*, of which *A*, *B* and *C* pertain to the strength and value of built-up tension members, *D* to the net area required back of pin holes in plates having sheared and planed ends, *E* to the tensile strength of single angles having ends riveted to connection plates, *F* to the strength of steel which has been worked partly hot and partly cold. These different series will be discussed in regular order.

Series A, Tests 1 to 10.—These tests were made with the view of ascertaining to what extent the individual pieces of built-up members

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will act together while under a tensile strain, the efficiency of different styles of webs or lacing, and whether the results, as compared with specimens, make a better or worse showing than those obtained from eye-bars.

There are five designs and two tests of each design, the detail drawings of which are given in Fig. 1. End connections were designedly made strong enough to insure rupture in the body of member, but attention is called to the eccentric attachment of pin plates to pieces 1 and 2, and to the more direct attachment to the others. In members 1, 2, 5 and 6 the rivets are so arranged that but one hole in each angle need be deducted in order to arrive at the net section, but in pieces 3, 4, 7, 8, 9 and 10 the rivets stagger by less that $\frac{3}{4}$ in., thereby reducing the gross section of each angle by the area of two holes, or else requiring this area to be determined by a zigzag line passing through the nearest holes. The rivets used were $\frac{1}{2}$ in. in diameter, holes were punched $\frac{9}{16}$ in. in diameter and assumed as $\frac{5}{8}$ in. in diameter in arriving at the net section. The ends of plates were simply sheared off.

The material was soft basic open-hearth steel rolled at Pencoyd for Tests 1 and 2, and by the Carnegie Steel Company for Tests 3 to 10. Pieces 1 and 2 were made and tested at Pencoyd, the others at Edge Moor.

Table No. 1 gives the results of specimen tests cut from the material used in the built-up members, the elastic limit having been determined by the drop of the beam and the elongation taken in a length of 8 ins.

TABLE No. 1.—Specimen Tests, Series A.

	Tests 1 and 2.	Tests 3 to 10.		
	Angles.	Angles.	Plates.	Average.
Elastic limit	40 700 lbs.	39 900 lbs.	36 600 lbs.	38 250 lbs.
Ultimate strength	58 200 lbs.	56 500 lbs.	59 300 lbs.	57 800 lbs.
Elongation	25.25%	26.20%	25.60%	25.90%
Reduction	62.50%	57.00%	57.00%	57.00%
Fracture	Silky.	Silky.	Silky.	Silky.

Table No. 2 contains all data in connection with the design of members in this series, the percentages being based on areas obtained from assumed stresses as follows: Tension, 15 000 lbs.; bearing on pins and rivets, 20 000 lbs.; shearing on rivets, 10 000 lbs.

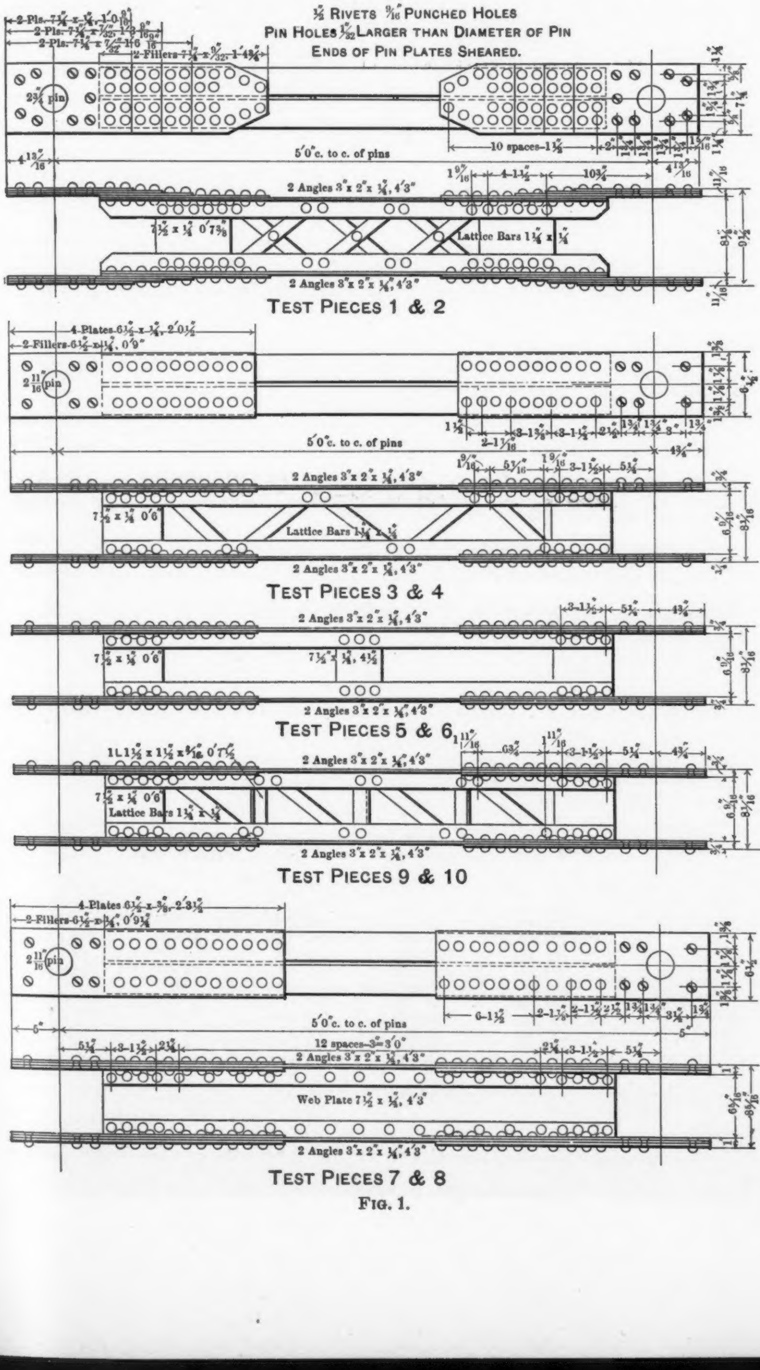

½" Rivets 9/16" Punched Holes
Pin Holes 1/32" Larger than Diameter of Pin
Ends of Pin Plates Sheared.
TEST PIECES 1 & 2
TEST PIECES 3 & 4
TEST PIECES 5 & 6
TEST PIECES 9 & 10
TEST PIECES 7 & 8

FIG. 1.

TABLE No. 2.—DATA RELATING TO MEMBERS OF SERIES A.

Mark.	Area.		Holes Deducted.	Percentage Excess.			
	Gross.	Net.		Bearing on pins.	Net Area.		Rivets.
					*Through pin holes.	*Back of pin holes.	
1 and 2......	4.80	4.18	4	21.1	47.6	12.9	50.5
3 and 4......	4.80	3.78	8	41.5	50.0	34.6	76.2
5 and 6......	4.80	4.18	4	28.2	35.6	21.8	59.4
7 and 8......	6.68	5.34	10	34.2	41.6	36.3	37.5
9 and 10.....	4.80	3.78	8	41.5	50.0	34.6	76.2

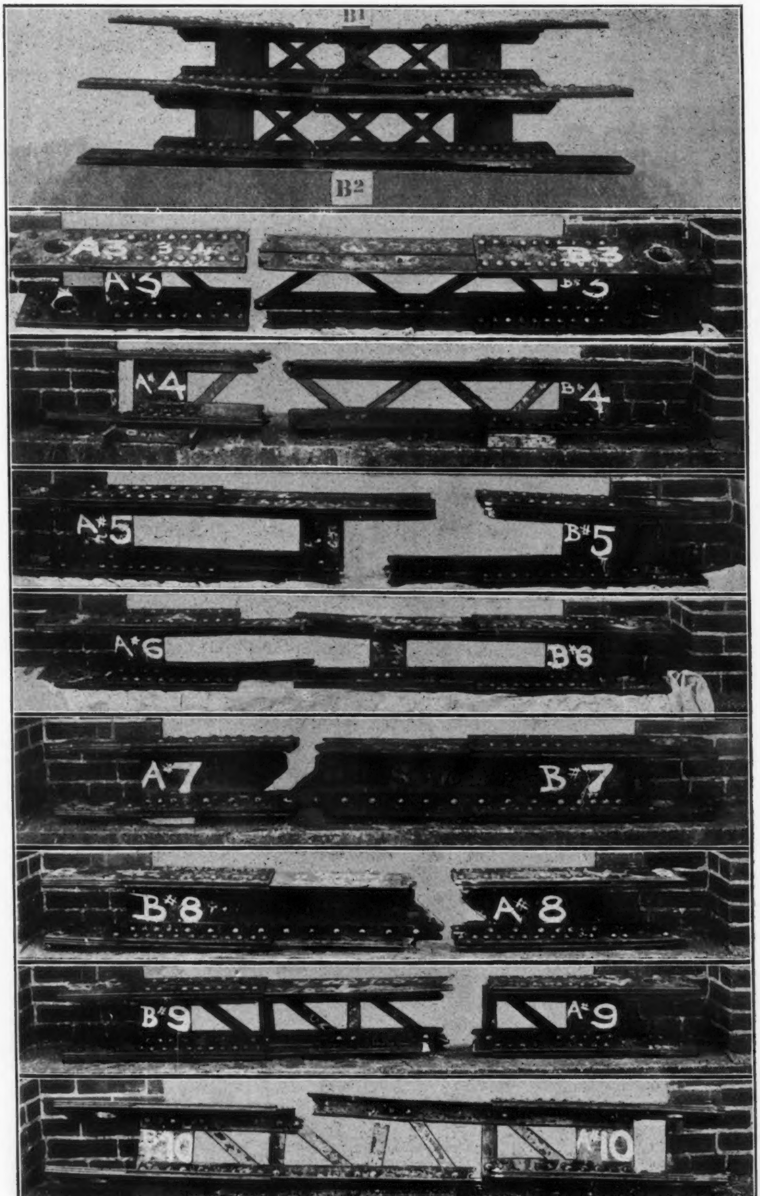
* The figures in these two columns represent the percentage of increased area over actual net area through body of member.

The elastic limit of the built pieces was determined by the action of the gauge and by observing the scaling of the members. The two observations agreed closely in all cases excepting Nos. 3 and 4 where the gauge determination was excessive by 9.1% for the former and 4.6% for the latter. The gauge determination is given in Table No. 3. Elongation is measured from back to back of pin holes.

TABLE No. 3.—RESULTS IN DETAIL OF TESTS IN SERIES A.

Mark.	Elastic Limit.		Ultimate Strength.		Elongation.
	Total.	Per square inch.	Total.	Per square inch.	
	Pounds.	Pounds.	Pounds.	Pounds.	Inches.
1...............	136 000	32 536	199 000	47 607	1.31
2...............	150 000	35 885	201 000	48 086	1.31
3...............	182 000	48 148	200 900	53 148	1.53
4...............	174 400	46 138	193 400	51 164	2.28
5...............	159 200	38 086	200 900	48 062	2.41
6...............	174 400	41 722	200 900	48 062	1.08
7...............	231 300	43 315	269 200	50 412	1.53
8...............	238 800	44 719	282 100	52 828	1.53
9...............	185 800	49 153	205 000	54 233	1.41
10..............	174 400	46 138	205 000	54 233	1.56

The average results, together with the percentage ratio of the developed strength to the strength of specimens, is given in Table No. 4.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B#8
A#8
B#9
A#9
B#10
A#10

TABLE No. 4.—AVERAGE RESULTS AND COMPARISON WITH SPECIMENS.

Mark.	Pounds Per Square Inch.		Comparison with Specimens.		Remarks.
	Elastic limit.	Ultimate strength.	Elastic limit.	Ultimate strength.	
1 and 2...........	34 211	47 847	84.0%	82.2%	Double lattice.
3 and 4...........	47 143	52 156	118.2%	92.3%	Single lattice.
5 and 6...........	39 904	48 062	100.0%	85.06%	Batten plates.
7 and 8...........	44 017	51 620	115.1%	89.3%	Solid web.
9 and 10..........	47 646	54 233	119.4%	96.0%	Zigzag lattice.

See Plate IX for the appearance of the members after fracture.

The pins used in the first two tests were slightly bent, and the pin holes elongated $\frac{1}{16}$ in. In Tests 3 to 7 the pins were of soft steel, and were bent and sheared considerably, the bending amounting to as much as $\frac{5}{8}$ in. in a length of 15 ins. The bent pins distorted the holes, and as the pull was transmitted through links taking hold of the pins on the outside of the plates, the bending had a tendency to force these pin plates together. In Tests 8 and 10 the pins were case-hardened and bent but $\frac{3}{16}$ in., with no perceptible shearing and no distortion of the pin holes. Fracture was generally clean and silky, with an occasional granular spot about the rivet holes. The rivets remained tight, with no indication of shearing except where noted.

Observations taken during tests are as follows:

No. 1. The lattice bars drew the flange angles in to a noticeable extent, while the jaws bent inward at the ends. Fracture began at the edge of the inner leg on a line with the rivets in the first pair of lattice bars, the cross-section of the angles contracting noticeably at the critical line before pulling apart.

No. 2. This was a duplicate of No. 1; it broke in a similar manner and had similar accompanying characteristics.

No. 3. The lattice bars pulled the flange angles together and the jaws contracted, but all distortion was of a much less extent than that observed in Tests 1 and 2. Fracture began at the edge of the outer leg on a line with the rivet in the lattice bar near the tie plate. Rupture of the other angles followed an instant later, but they were bent outward, due to the uneven pull after the first fracture.

No. 4. This was a duplicate of No. 3, broke in similar manner and had similar accompanying characteristics.

No. 5. The flanges between the tie plates bent outward while the jaws contracted to but a very small extent. Fracture began at the edge of the outer leg on a line with the rivets near the end of the pin plates. After both angles of this flange had broken, the opposite pair of angles ruptured suddenly through the end rivet of the center batten plate.

No. 6. This was a duplicate of No. 5. Fracture began in one angle through the last rivet in the pin plate while the other angle of the pair broke almost at the same instant through the end rivet of the center batten plate. The opposite pair of angles gave way at about the same time at points diagonally opposite the first two fractures. Jaws at the A end were slightly contracted, while the angles between the batten plates spread outward the same as in Test 5.

No. 7. The four angles broke almost simultaneously through the end rivets in the pin plate, the line of rupture on the web being irregular. The jaws were contracted slightly. There was no other distortion.

No. 8. This was a duplicate of No. 7, with similar fracture. The jaws were not so much contracted, and there was no distortion.

No. 9. Fracture began through the rivet hole at the foot of the second inclined lattice bar, and the adjacent angle gave way before the opposite pair broke on a line of rivets near the end of the pin plate. There was no perceptible deformation of the member except in the very small contraction of the jaws at the B end.

No. 10. This was a duplicate of No. 9. It began to fail through the rivet holes at the end of the pin plate, both angles of one pair breaking simultaneously. The piece then gradually swung around until the opposite angles broke through the rivet holes at the top of the second inclined lattice bar. The center stiffening angle broke on the line of the end rivet at about the same time. There was a very small contraction of the jaws at the B end, but no other deformation except that due to the uneven pull after the first fracture.

Through the courtesy of C. C. Schneider, M. Am. Soc. C. E., and Mr. Frank Heisler, Vice-President of Edge Moor Bridge Works, the author was furnished with comparisons of specimen and full-size tests of eye-bars made of acid and basic open-hearth and Bessemer steels, the average results of 70 tests being scheduled in Table No. 5, which also gives the ratio of the strength of the eye-bars to the strength of the specimens. The specimens were not annealed.

TABLE No. 5.—COMPARISON OF SPECIMEN AND FULL-SIZE EYE-BAR TESTS.

Material.	No. of Tests.	Specimens.		Full Size.		Percentage of strength developed.
		E. L.	Ult.	E. L.	Ult.	
Basic O.-H.........	10	38 250	65 600	31 130	60 300	91.9
Acid O.-H..........	15	36 990	65 520	30 160	57 910	88.4
Bessemer	14	37 780	60 840	32 370	55 800	91.7
Acid & Basic O.-H.	31	36 350	62 370	31 420	56 970	91.3
Average........	70	37 342	63 582	31 270	57 745	90.8

By comparing the percentages in Table No. 5 with the results given in Table No. 4, it will be observed that Tests 1, 2, 5 and 6 do not make as good a showing as eye-bars. Tests 7 and 8 are almost as good, while Tests 3, 4, 9 and 10 make even a better showing, so far as the ultimate strength is concerned. All tests in the series, with the exception of Nos. 1 and 2, show a very large elastic limit, while the elongation without exception was decidedly small.

The results of these tests seem to indicate that built-up I sections having double lattice bars for webs, such as Nos. 1 and 2, and those having batten plates, as Nos. 5 and 6, are not so effective as members with single lattice or solid webs. Double lattice drew the flange angles together and caused secondary bending strains which were not relieved even by the eccentric attachment of the pin plates, and the bending had a tendency to cause fracture to start from the edges of the inner legs of the angles at a rather low indicated stress.

Batten plates without lattice did not prevent an outward bending of the angles, and results were not much better than obtained for double lattice.

On the other hand, single lattice, such as in Nos. 3, 4, 9 and 10, and a solid web plate as Nos. 7 and 8, gave the least distortion. There is, therefore, so far as can be discovered from tests of this series, no reason why built-up members of these three types should not be used with the same unit stress as is allowed for eye-bars, and in cases of solid webs no reason why the web plate should not be considered as effective section. This is the practice with some engineers, although others insist upon lower stresses for built members used in tension. The continuation of these tests in series *B* and *C* may temper whatever conclusions one may draw from results of each series considered independently,

consequently series *A*, *B* and *C*, also possibly *D*, should be studied in conjunction with each other, and conclusions not be drawn too hastily.

Series B, Tests 11 to 18.—This series was made with the same object in view as outlined for Series *A*, and in addition an effort was made to ascertain whether the connection of both legs of the main angles to pin plates, as in pieces 15 to 18, would be of any material benefit.

There are four designs in pairs, each having two webs and four angles, the pins passing through the webs as shown in Fig. 2. The data in connection with the designs of these pieces are as follows: Gross area, 8.64 sq. ins.; holes deducted, 14, assumed to be $\frac{5}{8}$ in. diameter; net area, 6.72 sq. ins. on zigzag line. The sections through and back of the pin holes are excessive in every case.

The material was soft basic open-hearth steel rolled by the Carnegie Steel Company. Members were made and tested at Edge Moor.

The elastic limit in Table No. 6 was determined by the drop of the beam. The elongation was taken in a length of 8 ins.

TABLE No. 6.—Specimen Tests, Series B.

	Angles.	Plates.	Average.
Elastic limit	39 900 lbs.	36 600 lbs.	38 250 lbs.
Ultimate strength	57 900 lbs.	59 300 lbs.	58 600 lbs.
Elongation	27.00 %	25.60 %	26.30 %
Reduction	52.00 %	57.00 %	54.50 %
Fracture	Close silky.	Close silky.	Close silky.

The elastic limit of built members as determined by gauge and scaling agreed in all tests in Table No. 7, except Nos. 11, 12 and 14, in which cases scale began to drop at stresses of 45 200, 42 500 and 44 670 lbs. per square inch respectively. Elongation was measured back to back of pin holes the same as before.

TABLE No. 7.—Results of Tests in Detail, Series B.

	Elastic Limit.		Ultimate Strength.		Elongation. Inches.
	Total.	Per sq. in.	Total.	Per sq. in.	
	Pounds.	Pounds.	Pounds.	Pounds.	
11	341 200	50 774	348 800	51 904	0.94
12	254 000	37 798	326 000	48 512	1.94
13	314 700	46 830	375 300	55 848	1.81
14	269 200	40 060	341 200	50 774	2.31
15	307 100.	45 699	326 100	48 526	1.56
16	303 300	45 134	326 100	48 526	1.31
17	242 600	36 101	310 900	46 264	0.81
18	310 900	46 265	322 300	47 961	2.06

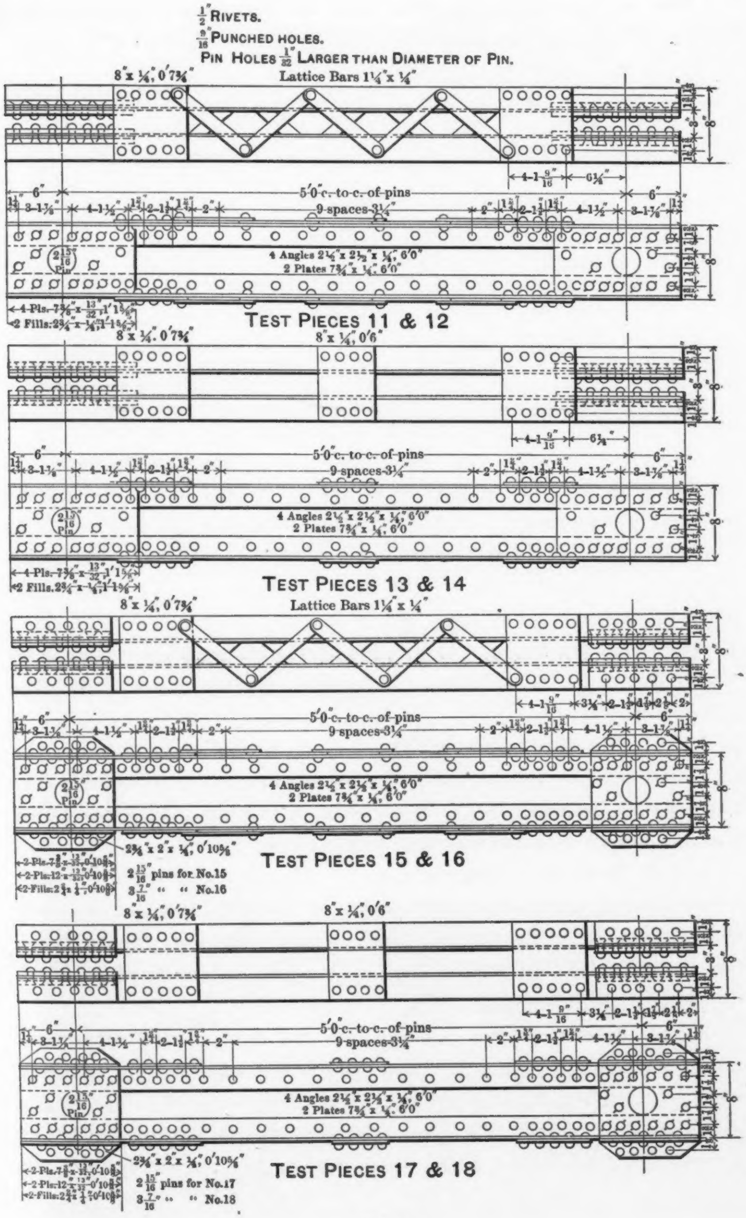
1/2" Rivets.
9/16" Punched holes.
Pin Holes 1/32" Larger than Diameter of Pin.
Lattice Bars 1¼" x ¼"
5'0" c. to c. of pins
9 spaces 3¼"
4 Angles 2½" x 2½" x ¼", 6'0"
2 Plates 7¾" x ¼", 6'0"
Test Pieces 11 & 12
Test Pieces 13 & 14
Test Pieces 15 & 16
2 15/16" pins for No.15
3 7/16 " " No.16
Test Pieces 17 & 18
2 15/16" pins for No.17
3 7/16 " " No.18

FIG. 2.

The average results, together with the comparison of strength of members with specimens, are given in Table No. 8.

TABLE No. 8.—Average Results and Comparison with Specimens.

	Pounds per Square Inch.		Comparison with Specimens.		
	Elastic limit.	Ultimate strength.	Elastic limit.	Ultimate strength.	Remarks.
11, 12..	44 286	50 208	115.8%	85.7%	Lattice bars. Narrow pin plates.
13, 14..	43 445	53 311	113.6%	91.0%	Batten plates. Narrow pin plates.
15, 16..	45 417	48 526	118.7%	82.8%	Lattice bars. Wide pin plates.
17, 18..	41 183	47 113	107.7%	80.4%	Batten plates. Wide pin plates.

See Plate X for the appearance of the members after fracture.

The pins used in Tests 11 to 15 were soft steel and were bent and sheared considerably, the bending amounting to $\frac{1}{16}$ in. in 15 ins. In Tests 16, 17 and 18 the pins were case-hardened, and the two $\frac{15}{16}$-in. pins bent $\frac{3}{16}$ in., while the three $\frac{7}{16}$-in. pins bent about $\frac{1}{16}$-in., without any shearing or measurable distortion of holes.

The fractures, except where noted otherwise, were silky and practically free from granulation. Other observations taken during the tests are as follows:

No. 11. Fracture began in one top angle which broke through the end rivet hole in the batten. The other parts followed quickly, the parts being distorted during the course of rupture. This distortion was not noticeable until the piece began to fail.

No. 12. This was a duplicate of No. 11. Fracture began through the end lattice rivet of one angle, and then continued through the plate and other angle. The first side had broken completely through before the opposite side began to fail. There was no noticeable distortion until failure began.

No. 13. Fracture began through one end rivet in the batten, and continued through both angles and the plate of one segment on a line with the end rivets in the pin plate. Tests were stopped before the adjacent segment failed. There was no observable distortion, but it was noticed that the angles had pulled out $\frac{1}{16}$ in. from under the pin plates.

PLATE X.
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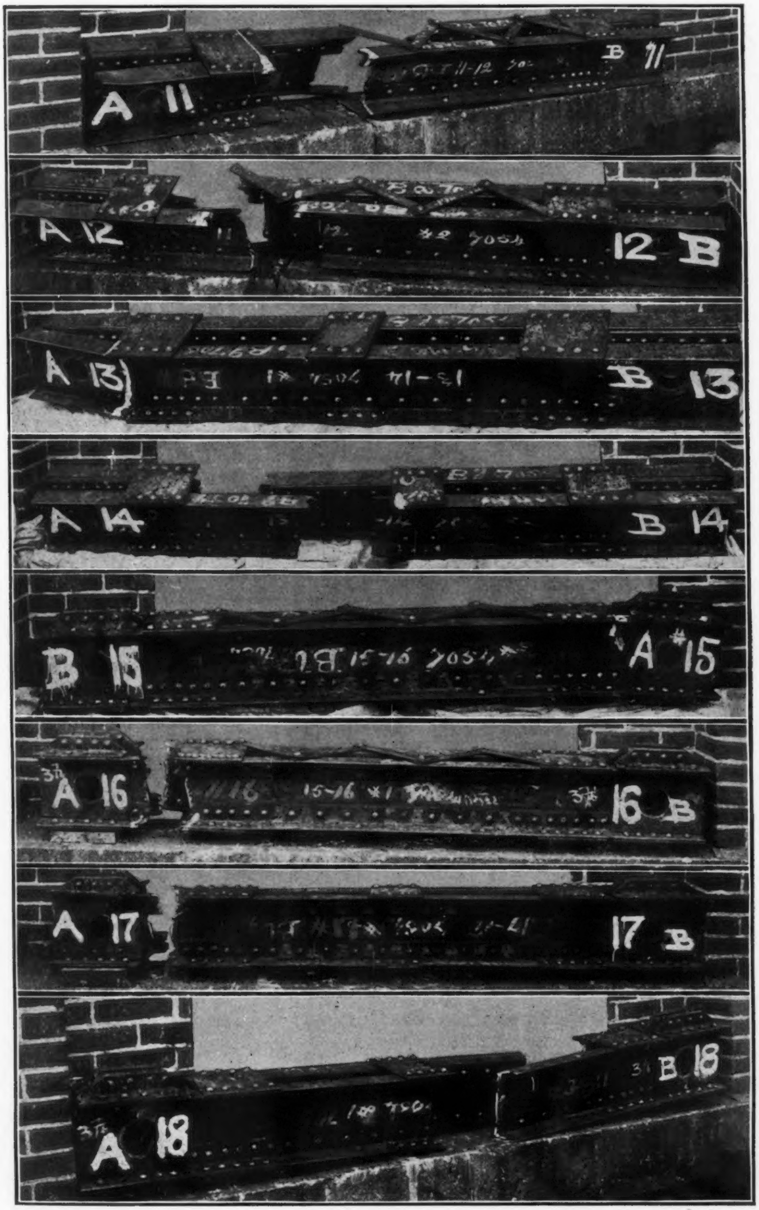

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No. 14. This was a duplicate of No. 13. The angles again pulled out perceptibly from under the pin plates. Fracture began through the end rivet in the center batten, the top angle first breaking through, then the web, then the bottom angle, and the whole of the other side simultaneously. There was no distortion until after fracture began.

No. 15. Broke at one side only at the end of the batten plate. The pin, which was not hardened, bent $\frac{11}{16}$ in. in a length of 15 ins., and the broken jaw bent outward and slipped off the pin. There was no observable distortion.

No. 16. This was a duplicate of No. 15, except the holes in this member were bored for three $\frac{7}{16}$-in. pins. Fracture started in the end rivet of the pin plate and went almost straight through the line of rivets in the plate. One batten rivet was sheared off. Fracture was coarsely granular in character where failure first began.

No. 17. Broke through the rivets near the end of the pin plates on both sides almost simultaneously. Examination after fracture revealed a crack in one angle across the rivet hole at the end of the end batten plate. Fracture showed considerable granulation.

No. 18. This was a duplicate of No. 17, except the holes were bored for three $\frac{7}{16}$-in. pins. It began to break through the end batten plate rivets on one side. After this side had broken through, the other side held for some time, finally giving way through the line of rivets in the middle batten. There was no distortion except what occurred during rupture.

It was expected that members designed with two web plates and four angles, having pins passing directly through the webs, would give better results than could be obtained from four angles connected together in pairs as in Series *A*. It was also expected that Tests 15 to 18 would be somewhat stronger than Tests 11 to 14, because in the former the pin plates were attached to both legs of the flange angles. These expectations were not realized.

As the pins in these four members had been case-hardened and bent very little during the testing, it is probable that the mere fact that the pin plates did not extend quite up to the first batten plates, will account for members 15 to 18 failing at lower stresses than members 11 to 14, which had longer pin plates to stiffen the jaws, although the members were subjected to the additional strains due to the bending of the soft pins. The attachment of the pin plates to both legs of the

flange angles was evidently of no benefit when taken in conjunction with short pin plates, but had the pin plates been longer, the author believes that the results would have been different.

These tests do not show any advantage of lattice bars over batten plates, members 11 and 12 with lattice giving worse results than similar members, 13 and 14, with battens, while latticed members 15 and 16 were better than similar members, 17 and 18, which had battens.

Members 13 and 14, with battens, are the only ones in the series which developed as high results as eye-bars. Members 11 and 12 (latticed) gave fair results, about as good as 5 and 6 with battens in Series *A*, members 15 and 16 (latticed) about as good as 1 and 2 (double latticed), while 17 and 18 (with battens) developed the least strength of any in the two series.

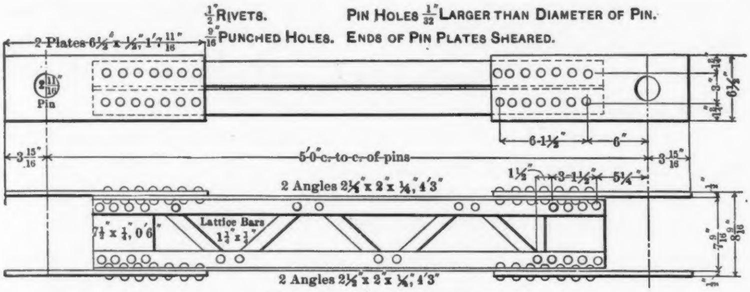
Series C—Tests 19 to 26.—The members in this series were designed on the basis of 10 000 lbs., 15 000 lbs., and 20 000 lbs., for shearing, tensile and bearing stresses respectively, little or no excess having been placed in any connection, but the pin plates in Tests 25 and 26 were made weaker on the line of the rivet holes than through the pin holes or the body of member.

The eight members tested covered four different designs, somewhat similar to those in Series *A*, but having the rivets so arranged that but one hole need be deducted from the gross area of each angle. The ends of the pin plates were sheared off (see Fig. 3).

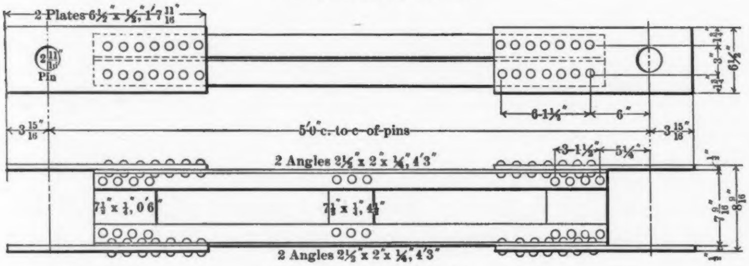
TABLE No. 9.—Data Relating to Members of Series C.

Members.	Area.		Holes deducted.	Percentage Increase or Decrease.				
	Gross.	Net		Bearing on pins.	Net Area.			Rivets.
					Through pin holes.	Back of pin holes.	Front of pin holes	
19 to 24	4.24	3.62	4	0.0	+4.4	— 4.63	+44.75	+1.1
25 and 26...	6.12 Pin plate.	5.18 4.25	6	+3.4	+2.3	—11.46	—21.9	+2.9

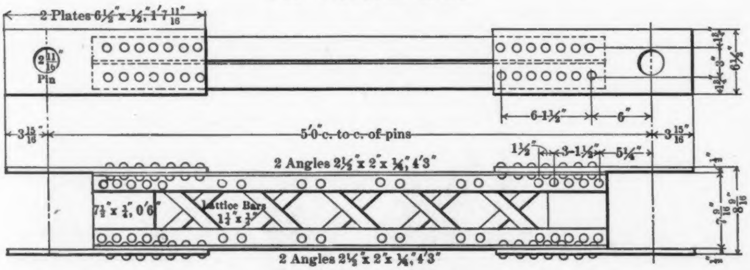
The negative percentage in this table for the area back of the pin holes was based on the assumption that the required area should equal three-fourths of the area across the pin holes, or, in other words, that this area should be proportioned for double shear on the shortest line from the edge of the hole.



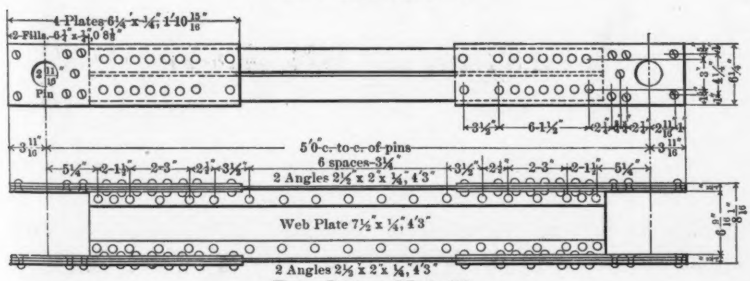
TEST PIECES 19 & 20



TEST PIECES 21 & 22



TEST PIECES 23 & 24



TEST PIECES 25 & 26

FIG. 3.

The material was soft basic open-hearth steel rolled by the Carnegie Steel Company. Members 19 to 22 were manufactured by Youngstown Bridge Company, 23 to 26 at Edge Moor, and all were tested at Edge Moor.

Specimens tested in the same manner as in Series *A* developed the properties given in Table No. 10.

TABLE No. 10.—SPECIMEN TESTS, SERIES C.

	ANGLES.	PLATES.
	Average of 4.	Average of 3.
Elastic limit	35 650 lbs.	38 750 lbs.
Ultimate strength	55 275 lbs.	56 515 lbs.
Elongation	28.75%	29.0%
Reduction	56.25%	58.5%
Fracture	Silky.	Silky.

The gauge determinations of the elastic limit of built members are given in Table No. 11. The limits as indicated by scaling were essentially the same, except in members 20, 22 and 24, where scaling was first noticed at 25 100 lbs., 37 200 lbs., and 34 700 lbs., per square inch respectively. The elongation was measured from back to back of pin holes.

TABLE No. 11.—RESULTS OF TESTS IN DETAIL, SERIES C.

Member.	ELASTIC LIMIT.		ULTIMATE STRENGTH.		ELONGATION.	
	Total.	Per square inch.	Total.	Per square inch.	Total.	Pin holes.
	Pounds.	Pounds.	Pounds.	Pounds.	Inches.	Inches.
19	166 800	46 080	174 400	48 180	1.62	0.25
20	106 000	29 280	178 200	49 230	Not taken.	0.25
21	151 600	41 885	182 000	50 280	" "	0.25
22	151 500	41 860	182 000	50 280	1.69	0.25
23	155 400	42 930	174 400	48 180	2.81	0.87
24	151 600	41 880	166 800	46 080	2.69	0.75
25	182 000	*42 830	212 300	*49 960	2.12	0.56
26	189 500	*44 590	219 900	*51 740	Not taken.	0.44

* The strain per square inch of members 25 and 26 was taken on a section through the weakest part of the pin plate.

The average results of tests, together with comparisons with specimens, are given in Table No. 12. This table, however, is to be studied cautiously, inasmuch as Nos. 19 and 20 are the only mem-

PLATE XI.
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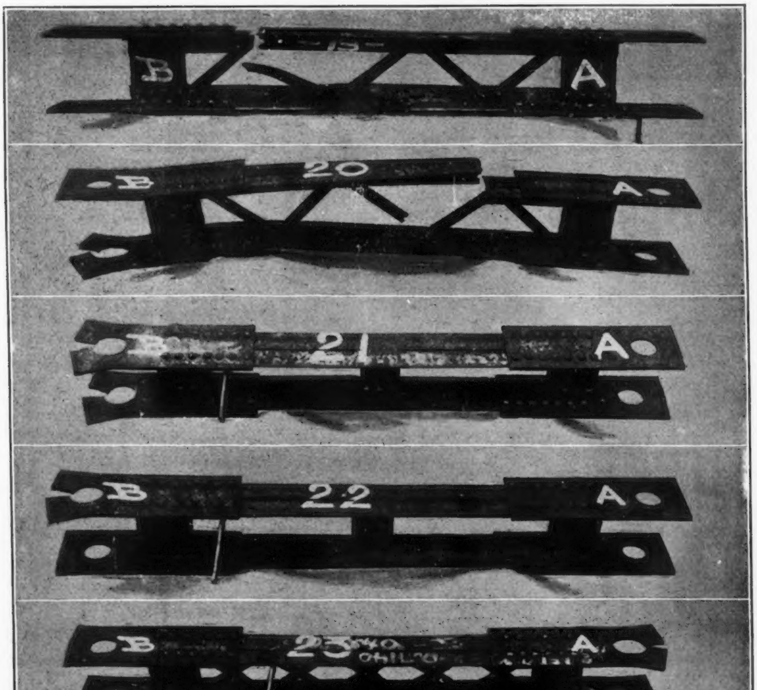

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bers which broke through the body, the others having given way back of the pin holes or through the pin plates in front of the pins. The percentages of developed strength are based on stresses on the net section through the body, except in Nos. 25 and 26, where the net section is the least through the rivets in front of the pin holes.

TABLE No. 12.—Average Results and Comparison with Specimens.

	Pounds per Square Inch.		Comparison with Specimens.		Remarks.
	Elastic limit.	Ultimate strength.	Elastic limit.	Ultimate strength.	
19 and 20...........	37 680	48 705	105.7%	88.1%	Single lattice.
21 and 22...........	41 872	50 280	117.5%	91 0%	Battens.
23 and 24...........	42 405	47 130	119.0%	85.3%	Double lattice.
25 and 26...........	43 710	50 850	112.8%	90.0%	Web.

The pins used were case hardened, and bent so slightly that it was necessary to change but once during the testing.

The illustrations on Plate XI should be compared with the following notes of observations taken during the progress of the tests:

No. 19.—First rupture occurred at end B, both angles breaking through the second lattice rivet, one rather suddenly, the other with slightly more tenacity. A crack also appeared in the same angles through the end rivets of the pin plate at the same end. After breaking through on this side, the member swung slowly round, and the other two angles broke through the third lattice rivet from the B end, tearing rather than snapping. On one side of the member the fracture of the upper angle was silky and of the lower wholly crystalline, while on the opposite side these conditions were reversed. There was very small distortion in any part of the member, except what occurred after one side had broken.

No. 20.—This was a duplicate of No. 19. The rupture in this member began at end A, at the same point as in the previous case, both angles failing at the same time. The member then swung around, splitting the middle lattice bar away from its rivet and failing at end B by splitting the pin plate back of the pin hole. The fracture through the angles at end A was wholly silky, while the crack in the pin plate had a fibrous appearance. One pin plate at end A was drawn in about $\frac{1}{4}$ in. around the pin hole, with a perceptible bulging

out at the end, with several cracks starting. The distortion shown in the illustration took place after the angles fractured.

No. 21.—Batten plates. This member broke out back of the pin plates in end B, both pin plates failing simultaneously, one with a coarse granular or crystalline, and one with a fibrous, fracture. The deformation of the member in this case was considerable, and it was drawn in about $\frac{1}{4}$ in. near the middle batten, or rather it was bulged out this amount between the battens. Both pin plates at end A started to crack in the end.

No. 22.—This was a duplicate of No. 21. It broke suddenly through one pin plate at end B, with crystalline fracture. There were cracks in the end of both pin plates at end A. The member was slightly bent, but not to the extent observed in No. 21.

No. 23.—Double lattice. This broke suddenly through one pin plate at end A, the other pin hole at this end elongating about $\frac{7}{8}$ in. At end B both pin holes were elongated $\frac{3}{4}$ in., and the plates showed cracks in the ends. There was a perceptible reduction of section at the pin holes. The member was considerably distorted about the jaws, and the two flanges were drawn together perceptibly by the pull of the lattice.

No. 24. This was a duplicate of No. 23. One pin plate at end A broke out to the end, the other pin hole elongating $\frac{3}{4}$ in. The fracture had a fibrous appearance. At end B both pin holes were elongated $\frac{9}{16}$ in. and showed cracks in the ends of the plates. There was considerable contraction of area through the pin holes and distortion due to the pull of the lattice bars, the same as noted in No. 23.

No. 25. Web plate. The pin plates on one side at end A curled over, the part back of the pin convexing outward and the pin hole elongating $\frac{13}{16}$ in. All three plates at this point were cracked at the ends, but did not break out. The pin plates on the opposite side at this end broke off suddenly with a fine silky fracture, the outside one through the three rivets at the end of the filler farthest from the pin, the inside one through the first row beyond. The reduction of section through both points of fracture was marked, both at this end and the corresponding points at end B. All the pin plates at the B end were cracked in the end.

No. 26. This was a duplicate of No. 25. The pin plates at both sides at end A broke simultaneously in the same manner as in Test 25,

with the same conditions of cracks and reduction at end B. The fracture was fine silky.

No rivets were sheared off in any of the tests, nor were any found loose enough to be detected with the fingers. There was, however, a very general pulling away from the rivets noticed, both in the pin plates and in the lacing, arising no doubt partially from a shearing action and partially from an elongation of the holes.

It is to be noticed that in this series the members having batten plates were better than those having single lattice, just the reverse of results in Series *A*. The developed strength was 91%, which is about equal to the strength of eye-bars and considerably in excess of similar members numbered 5 and 6, which developed but 85.06 per cent.

The strength of the members numbered 19 and 20 (single lattice) was lower than that of eye-bars and much lower than similar members numbered 3 and 4.

The author cannot account for these results unless they are due to the hardened pins used in Series *C*, which may possibly have given more direct stress than was obtained from the soft pins in Series *A*, in which case it would appear that built I members with battens are just as effective as similar members with lattice bars.

Members numbered 23 and 24 show up better than similar members numbered 1 and 2, although the pin plates did not develop the full strength through the body of the member. Members numbered 25 and 26 (web plates) failed in the weakest part of the connection, and the tests show nothing except that connection plates of this size, strained in this manner, gave results 10% less than given by specimens.

The tests seem to show that pin plates having sheared ends should have a net area back of the pin holes of not less than 75% of the net area through the pin holes. They also apparently sustain the assumed relative values of 10 000, 15 000 and 20 000 lbs. respectively for shearing, tensile and bearing stresses.

Résumé of Series A, B and C.—The natural query upon the completion of a number of tests is what are the conclusions. Conclusions, however, are indicated rather than proved in most cases pertaining to limited investigations concerning structural material. The following conclusions, therefore, are no exceptions to the general rule, and are merely those which appear to the author to be indicated by the results

of the 26 tests in Series *A*, *B* and *C*. All facts in connection therewith are given in the paper. The indicated conclusions are as follows:

First.—Built I-shaped tension members composed of four angles connected in pairs by single lattice bars, or by batten plates spaced at short intervals, and having the end connection plates riveted to the projecting legs of the flange angles, will develop an ultimate strength which, when compared with tests of specimens cut from the member, will be proportionately as high as the ultimate strength of eye-bars compared with their specimens, when the eye-bars are annealed and the specimens not annealed.

Second.—Similar members with solid webs instead of lattice or battens are fully as strong per unit of section, and the full net area of web plates can be taken with the flange angles as available section, provided the area of web plates does not exceed one-half the area of the four angles, and the width of the plate in the clear of the flange angles does not exceed the width covered by the legs of the flange angles.

Third.—Similar members with double-latticed webs are probably inferior to any of the above, and their ultimate strength is proportionately less than the ultimate strength of eye-bars.

Fourth.—Similar members with open webs having lattice bars arranged alternately perpendicular and inclined to the long axis of the member, will show the least distortion when pulled to destruction, and will give the highest ultimate strength.

Fifth.—Box-shaped sections composed of two web plates and four angles, connected top and bottom by lattice or battens, and having pin connections through the web plates are, as tension members, no better than, if as good as, built I sections.

Sixth.—Segments of box-shaped members when connected by single lattice or batten plates, placed at short intervals, show no particular advantage of the lattice bars over the batten plates.

Seventh.—Nothing can be gained in box-shaped tension members by connecting the pin plates to both the vertical and horizontal legs of the flange angles, when the pin plates do not extend beyond the end rivets in the end batten plates.

Eighth.—The relative values of 10 000 lbs., 15 000 lbs., and 20 000 lbs., respectively, for shearing, tensile and bearing stresses are about correct, but there is an indication that the bearing values should be somewhat less.

Series D, Tests 27 to 42.—Sixteen test pieces, numbered from 27 to 42 in Fig. 4, were designed so that the area of the section back of the pin holes varied from about 32% to 96% of that across the holes. The tests are divided into four groups, A, B, C and D, there being four tests to each group, two with sheared ends and two (designated by letter M)

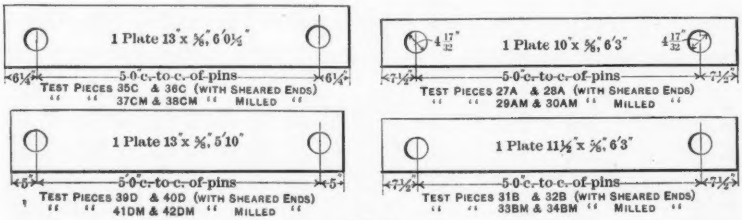

FIG. 4.

with milled ends. The material was soft open-hearth steel made and tested at Pencoyd. The object of the tests was to ascertain the proper amount of material required back of the holes in pin plates, and also what benefit can be derived from milling the ends.

Specimens cut from the various plates developed the properties given in Table No. 13.

TABLE No. 13.—SPECIMEN TESTS, SERIES D.

Size.	10 × ⅝ in.	11½ × ⅝ in.	13 × ⅝ in.
Elastic limit	42 500 lbs.	34 100 lbs.	35 500 lbs.
Ultimate strength	60 300 lbs.	54 700 lbs.	58 700 lbs.
Elongation	38 25%	34.00%	28.25%
Reduction	62.00%	64.00%	51.80%
Fracture	S cup.	S. ½ cup.	S. ang.

In Table No. 14 will be found all data and details of the results of the tests, the ratio in the fourth column being the ratio of the net area back of the pin holes to that across pin holes. Attention is called to the comparatively high ultimate strength given for Test 28 A. In view of the fact that it is so much greater than the three others of the same group, and that there is no apparent cause for this, the author is inclined to question the accuracy of the reading, and has therefore not considered this test in the comparative result given in Table No. 15.

TABLE No. 14.—RESULTS OF TESTS IN DETAIL, SERIES D.

Member.	Net Section.		Ratio.	Total.		Per Square Inch.			
						Elastic limit.		Ultimate strength.	
	Across hole.	Back of hole.	$\frac{\text{Back}}{\text{Across}}$.	Elastic limit.	Ultimate strength.	Through pin	Back of pin.	Through pin.	Back of pin.
	Sq Ins.	Sq. Ins.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
27 A..........	3.42	3.27	.96	96 000	165 000	28 100	29 300	48 300	50 400
28 A.	3.42	3.27	.96	101 000	201 600	29 500	30 900	59 000	61 600
29 AM.........	3.42	3.27	.96	98 000	162 000	28 700	30 000	47 400	49 500
30 AM.....	3.42	3.27	.96	100 000	163 000	29 300	30 600	47 700	49 800
31 B....	4.36	3.27	.75	74 000	177 000	17 000	22 600	40 600	54 100
32 B......	4.36	3.27	.75	54 000	185 000	12 400	16 500	42 500	56 500
33 BM	4.36	3.27	.75	90 000	170 000	20 700	27 500	39 000	52 000
34 BM.........	4.36	3.27	.75	54 000	177 000	12 400	16 500	40 600	54 100
35 C..........	5.29	2.49	.47	92 400	178 000	17 500	37 100	33 600	71 500
36 C...........	5 29	2.49	.47	110 000	180 000	20 800	44 200	34 000	72 300
37 CM.........	5.29	2.49	.47	85 000	225 000	16 000	34 100	42 500	90 400
38 CM....	5.29	2.49	.47	77 000	225 000	14 600	30 900	42 500	90 400
39 D......	5.29	1.71	.32	120 000	141 000	22 700	70 200	26 600	82 500
40 D....	5.29	1.71	.32	82 000	141 000	15 500	48 000	26 600	82 500
41 DM....	5.29	1.71	.32	54 000	193 000	10 200	31 600	36 500	112 900
42 DM....	5.29	1.71	.32	57 000	195 000	10 800	33 400	36 800	114 100

Table No. 15 gives the average results, comparisons with specimens cut from the plates, comparisons of results of milled and sheared ends, and the ratio of the width to the thickness of plates for all tests in Series *D*, also for the four plates which broke back of pin holes in the tests of Series *C*. The latter are given for convenient study in this connection.

TABLE No. 15.—AVERAGE RESULTS AND COMPARISONS.

Members.	Ratios.		Pounds per Square Inch.		Ratios.	
	$\frac{\text{Width.}}{\text{Thickness.}}$	$\frac{\text{Back of P. H.}}{\text{Across P. H.}}$	Specimen.	Developed	$\frac{\text{Developed.}}{\text{Specimen.}}$	$\frac{\text{Milled}}{\text{Sheared.}}$
A (one test).	16.0	.96	60 300	48 300	.80	
AM.........	16.0	.96	60 300	47 550	.79	.98
B...........	18.4	.75	54 700	41 550	.76	
BM......	18.4	.75	54 700	39 800	.73	.96
C.......	20.8	.47	58 700	33 800	.58	
CM.....	20.8	.47	58 700	42 500	.72	1.26
D......	20.8	.32	58 700	26 600	.45	
DM.........	20.8	.32	58 700	36 650	.62	1.38
Series C.....	13.0	.68	55 840	46 140	.83	

The test pieces were placed in the machine in such a manner that at the top of the plate there was no support back of the pin, while at

the bottom there was more or less support given by the jaws which took hold of the pin on each side of the plate. Had the tops been held instead of being absolutely free, the results would in all probability have been different, and would have furnished the information sought. As the results stand, however, the proper ratio of the area back of holes to that across holes is not definitely indicated, and owing to the buckling of the unsupported metal back of the holes in nine test pieces, the benefit of milled ends is not apparent except for those members which did not buckle.

In actual practice, the ends of the pin plates are not usually supported by adjacent members, and these tests therefore are in accord. Similar results would probably follow the testing to destruction of many tension members, now parts of bridges in service.

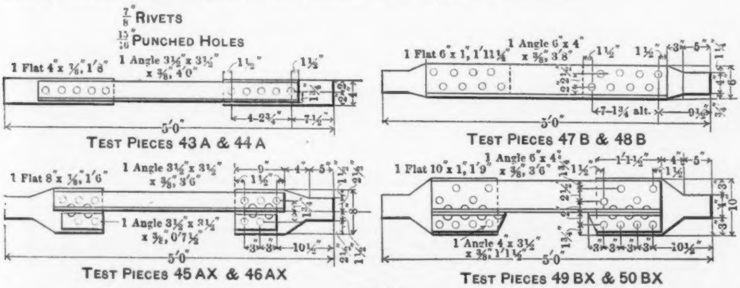

FIG. 5.

A study of results as given in Tables Nos. 14 and 15 will show that the following points have been brought out by the tests:

First.—Pin plates in which the area back of the holes was greater than 75% of the area through the holes, buckled and curled at the unsupported end before breaking out, and the milled ends were no stronger than the sheared ends. Those having a ratio less than 75% broke out without buckling, and the milled ends developed largely increased strength.

Second.—The developed stress, per square inch of area, back of the holes varied inversely, while the stress per square inch across the holes varied directly as the amount of metal back of the holes.

Third.—Buckling back of the holes took place in all members in which the ratio of width to thickness was greater than thirteen.

It is evident that had the plates been thicker, there would have been less tendency to buckle. The proper amount of material back of the pin holes, therefore, is not merely a function of the area across the

holes, but is some function of the area across the holes, the thickness of the plate, and the diameter of the pins, and cannot be definitely determined from the results of the tests made.

Series E, Tests 43 to 50.—The eight tests, in this series, were made for the purpose of comparing the strength of angles of the same dimensions, some having both legs and others but one leg riveted to gusset plates, the ends of the gussets being clamped in the testing machine so as to give, as nearly as possible, conditions similar to those in actual practice (see Fig. 5).

The material used was soft open-hearth steel rolled at Pencoyd, at which place all tests were made.

Specimens cut from angles had the properties shown in Table No. 16, which gives the average of two tests cut from each size of angle.

TABLE No. 16.—SPECIMEN TESTS, SERIES E.

	$3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$ Ins.	6 x 4 x $\frac{3}{8}$ Ins.
Elastic limit	38 850 lbs.	36 300 lbs.
Ultimate strength	59 350 lbs.	55 200 lbs.
Elongation	28.88%	33 38%
Reduction	56 85%	64.80%
Fracture	Silky.	Silky.

Results of the tests of these members are given in Table No. 17, the elastic limit having been determined by the dropping of scale, instead of by the dropping of the beam, and the unit stresses are based on the least net area, whether it be on a straight or broken line. Members marked A represent $3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$-in. angles, those marked B 6 x 4 x $\frac{3}{8}$-in. angles, while the letter X denotes that both legs are connected to gussets, and its omission that but one leg is connected.

TABLE No. 17.—RESULTS, IN DETAIL, OF TESTS, SERIES E.

No.	Area.		Elastic Limit.		Ultimate Strength.	
	Gross.	Net.	Total.	Per sq. in.	Total.	Per sq. in.
	Sq Ins.	Sq. Ins.	Pounds.	Pounds.	Pounds.	Pounds.
43 A	2.51	2.14	45 000	21 028	99 000	46 261
44 A	2.51	2.14	57 000	26 635	91 000	42 523
45 AX	2 51	1.99	56 000	28 141	105 300	52 914
46 AX	2.51	1.99	50 000	25 125	102 700	51 608
47 B	3.60	3.06	76 000	24 837	128 000	41 830
48 B	3.60	3.06	72 000	23 529	129 300	42 255
49 BX	3.60	3.08	94 000	30 519	153 000	49 675
50 BX	3.60	3.08	80 000	25 974	154 000	50 000

PLATE XII.
PAPERS AM. SOC. C. E.
MAY, 1897.
GREINER ON TESTS OF BRIDGE MEMBERS.

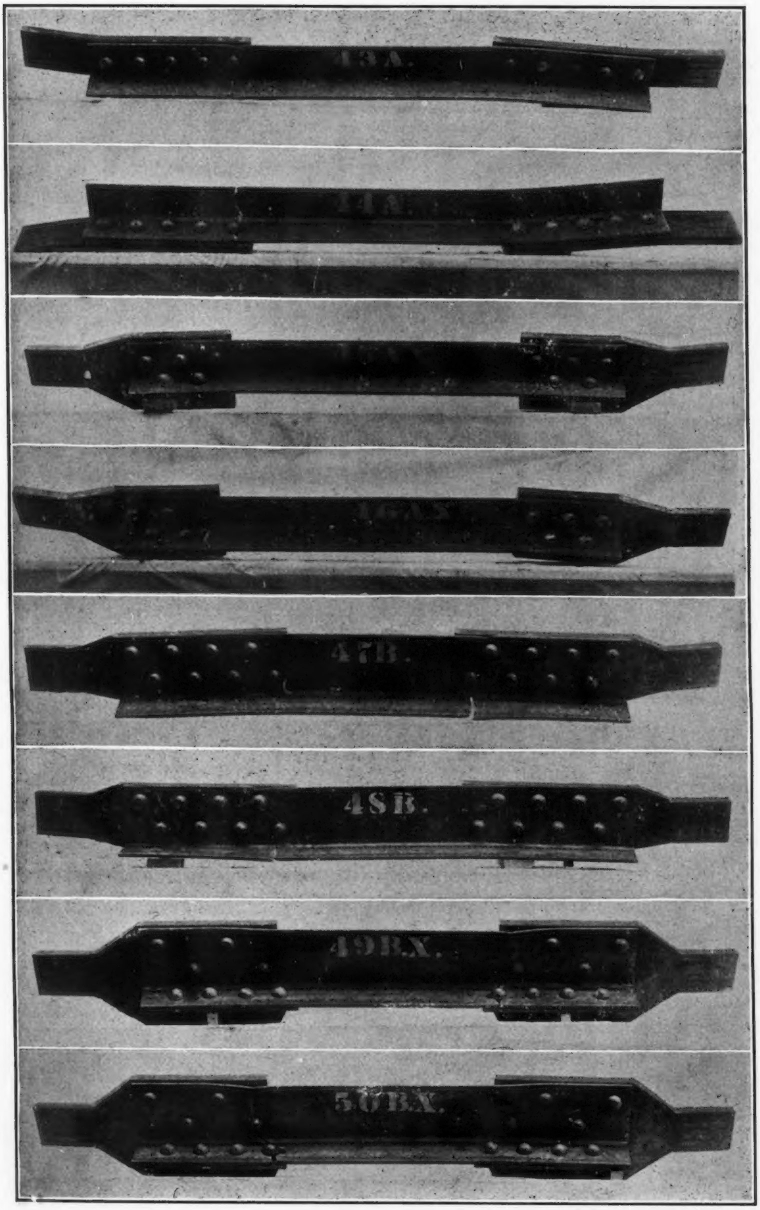

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Table No. 18 gives the average results and comparisons of the two styles of connections, based on the total elastic limit and the total ultimate.

TABLE No. 18.--COMPARISONS, SERIES E.

Sizes.	Legs connected.	Elastic Limit.		Ultimate Strength.	
		Total.	Increase.	Total.	Increase.
Inches.		Pounds.	Percentage.	Pounds.	Percentage.
$3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$	One.	51 000	....	95 000	
$3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$	Two.	53 000	3.92	104 000	9.5
6 x 4 x $\frac{3}{8}$	One.	74 000	....	128 650	
6 x 4 x $\frac{3}{8}$	Two.	87 000	17.57	153 500	19.3

The average elastic limit and ultimate str ength per square inch of least net section, also the percentage comparisons with specimen tests are given in Table No. 19.

TABLE No. 19.—AVERAGE RESULTS, COMPARED WITH SPECIMENS.

Tests.	Sizes.	Legs Connected.	Pounds per Square Inch.		Comparison with Specimens.	
			Elastic limit.	Ultimate strength	Elastic limit.	Ultimate strength.
	Inches.					
43, 44......	$3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$	One	22 832	44 392	61.3%	74.8%
45, 46	$3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{3}{8}$	Two.	26 633	52 261	68.6%	88.1%
47, 48......	6 x 4 x $\frac{3}{8}$	One.	24 183	42 042	66.6%	76.2%
49, 50	6 x 4 x $\frac{3}{8}$	Two.	28 247	49 838	77.8%	90.3%

The appearance of the different angles after fracture is shown on Plate XII. Pieces 45 and 46 broke square across through one rivet hole, the rivets being staggered $1\frac{1}{2}$ ins.; 47 and 48 broke diagonally through two holes which were staggered $1\frac{1}{2}$ ins., and 49 and 50 broke diagonally through two holes which were staggered $1\frac{1}{2}$ ins. All rivets except those at ends of connection plates were tight after fracture. The rivets at the ends of the connection plates gave evidence of shearing.

By referring to Table No. 18 it will be seen that when both legs are connected there is a gain in ultimate strength of about 9.5% for $3\frac{1}{2}$ x $3\frac{1}{2}$-in. angles, and about 19.3% for the 6 x 4-in. angles; also that there is a gain in the elastic limit.

The single angles developed a strength of from 74.8% to 76.2% of the ultimate strength of the specimens, which is considerably below the average developed strength of eye-bars, but the double connection gave results practically as high as those obtained with bars.

There is no question as to the superiority of the double connection, and it should be used whenever practicable and when conditions require rigidity. On the other hand, the single connection is not so weak as is usually supposed, the developed strength being, so far as these tests go, about 83% of the developed strength of eye-bars, as can be seen by comparing the percentage of developed strength of the angles given in Table No. 19, with the average developed strength of the bars given in Table No. 5.

Series F.—This series of tests was made for the purpose of ascertaining to what extent a good structural steel will be damaged, if a part is heated and bent while the other part remains cold. Will an area of weakness develop somewhere between the heated and unheated portions ? Will it become brittle or unreliable ? Is it absolutely necessary in all cases to anneal the entire piece ?

The fact that steel eye-bars, when not annealed, will sometimes break through or near the neck, and when partly annealed, through a section somewhere near the black heat area, led to the general practice of requiring that all members which have been partly heated must be annealed. There is no question concerning the beneficial effects of annealing when done properly, but cases sometimes arise when annealing in a furnace becomes impracticable, and the member must be used without any annealing, or resort must be had to the questionable wood fire. The author was recently called upon to decide such a case, and stipulated that if a series of tests indicated that an angle bent partly hot and partly cold did not become brittle, or was not injured to a greater extent than when the entire angle was bent cold, he would waive annealing for the members in question. The six groups of tests given in Table No. 20 were then made, and as the results did not indicate any marked superiority of the cold-worked angles over those which had one end worked hot, and as no brittleness or particularly weak area was found to exist in the steel tested, the manufacturer was allowed to heat and bend his angles without annealing. The author does not wish to be misunderstood as to his stand in this particular case. The angles in question were not to be used in a

railroad bridge, but in a roof truss subjected to but little vibration and no shock. If cold-bent angles were good enough for this case, then those bent hot and not annealed were no worse.

TABLE No. 20.—SPECIMENS CUT FROM UNWORKED MATERIAL.

Cut from.	PHYSICAL PROPERTIES.			CHEMICAL PROPERTIES.			
	Elas. lim.	Ult. str.	Elong.	Carbon.	Phos.	Mn.	S.
	Pounds.	Pounds.	Pounds.				
6 x 3½ x ⅜-in. angles..	36 000	62 100	30.0	0.17	0.015	0.40	0.038
5 x 3 x ⅜-in. angles....	38 700	66 700	28.75	0.24	0.016	0.45	0.040
3½ x 2½ x ¼-in. angles	39 800	60 600	28.75	0.19	0 017	0 45	0.040
3 x 2 x ¼-in. angles....	39 000	61 200	27.5	0.24	0.021	0.45	0.038
3 x ½-in. flats..........	39 500	62 000	25.0	0.22	0.010	0.47	0.040
1-in. square rods.......	36 000	60 300	31.0	0.21	0.015	0.46	0.039

The tests were divided into six groups, and, except where otherwise noted, were bent in a gag press to a circular arc, the ordinate of which was measured to a 2-ft. chord. The sizes of the test pieces are shown in Fig. 6.

Punching was not regular, the holes varying in number from 5 to 7, and in center to center distance from 3 to 6 ins.

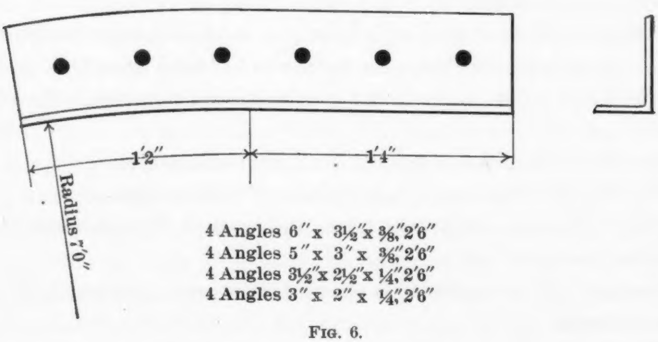

FIG. 6.

Group 1.—Four angles 2 ft. 6 ins. long, one of each size, were prepared by heating one-half length, bending, and then punching after the pieces became cold.

The 6 x 3½ x ⅜-in. angle bent 3½ ins. without developing cracks. It was then hammered out flat and cracked along the root about 6 ins. on each side of the center. A short crack was produced across the root

about 8 ins. from the cold end. There were slight cracks in the rivet holes.

The 5 x 3 x $\frac{3}{8}$-in. angle bent about $3\frac{1}{2}$ ins., without injury. It was then hammered out flat and cracked for a distance of 3 ins. across the root at the center of the piece.

The $3\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$-in. angle bent $3\frac{5}{8}$ ins. before a crack started from the hole near the center of the piece. The angle was broken by continued gagging. The fracture was silky, with no granulation.

The 3 x 2 x $\frac{1}{4}$-in. angle bent 4 ins., when two cracks started at holes $8\frac{1}{2}$ and $11\frac{1}{2}$ ins. from the cold end. The angle was broken by continued gagging. The fracture was granular from the hole to the root of the angle.

Group 2.—Four angles as in Fig. 6, bent and punched cold.

The 6 x $3\frac{1}{2}$ x $\frac{3}{8}$-in. angle was not bent by gagging. While being hammered out flat, it cracked along the root.

The 5 x 3 x $\frac{3}{8}$-in. angle was not bent by gagging. While being hammered out flat it cracked along root.

The $3\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$-in. angle bent $3\frac{1}{2}$ ins., and cracks started in holes 12 and 15 ins. from the straight end.

The 3 x 2 x $\frac{1}{4}$-in. angle bent $3\frac{1}{4}$ ins., and a crack started in a hole 15 ins. from the straight end.

Group 3.—Four angles as in Group 1, one-half length heated and bent. They were punched after the pieces had been annealed.

The 6 x $3\frac{1}{2}$ x $\frac{3}{8}$-in. angle bent 3 ins., and a crack started in the rivet holes.

The 5 x 3 x $\frac{3}{8}$-in. angle bent $3\frac{7}{8}$ ins., without cracking.

The $3\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$-in. angle bent $3\frac{3}{4}$ ins., without cracking.

The 3 x 2 x $\frac{1}{4}$-in. angle bent 2 ins., and cracked through a hole 8 ins. from the unheated end.

Group 4.—Four angles as in Group 1, bent and punched cold and then annealed.

The 6 x $3\frac{1}{2}$ x $\frac{3}{8}$-in. and 5 x 3 x $\frac{3}{8}$-in. angles bent $2\frac{1}{2}$ ins., without cracking.

The $3\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$-in. angle bent $3\frac{3}{4}$ ins., without cracking.

The 3 x 2 x $\frac{1}{4}$-in. angle bent $4\frac{5}{8}$ ins., without cracking.

Group 5.—Two rods 1 in. square by 2 ft. 6 ins. long were heated for one-half their length and cooled in the open air. These rods were each placed in a testing machine and were struck several sharp blows

with a hammer while under loads of 25 000, 30 000 and 35 000 lbs. Both broke in the middle at a stress or 58 700 lbs. and a reduction of 50 per cent. The fracture was silky.

Group 6.—Four flats 3 ins. by $\frac{1}{2}$ in. by 2 ft. 6 ins. were heated for one-half their length and cooled in the open air. Two of them were bent at the center to 180° and closed down with a slight crack opening in one. One flat was nicked at the heated and unheated ends and at the middle. The ends were bent 180° to a 1-in. circle, and the middle 180° to a 3-in. circle, before breaking. The fracture in all cases was fine and silky.

The fourth flat was nicked in the middle, bent 180° and flattened down without fracture.

From these tests the benefits of annealing in Group 4 are apparent, as no cracks whatever developed, although the members were bent as much as possible by the gag. The two larger angles twisted to such an extent that the bending could not be carried to the same point as in the other groups.

There was no apparent benefit derived by annealing and then punching, as in Group 3.

The impact tests in Group 5 and bending tests in Group 6 failed to reveal any injury due to partly heating steel of this character, except that the ultimate strength was reduced, which, however, does not indicate anything, except that the piece had been softened the same as it would have been by annealing.

Conclusion.—In conclusion, the author wishes to state that while the foregoing six series of tests are incomplete and do not prove anything definite, they have at least developed suggestions which may be regarded as useful information, and which should encourage further investigation by those who have the opportunity. The author also begs to acknowledge the courtesies extended by the bridge companies which furnished the facilities for making the tests, and the thoroughness with which Mr. W. R. Edwards, his assistant, carried out instructions while the testing was in progress.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS.

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THE POWER PLANT, PIPE LINE AND DAM OF THE PIONEER ELECTRIC POWER COMPANY AT OGDEN, UTAH.

By HENRY GOLDMARK, M. Am. Soc. C. E.

TO BE PRESENTED AT THE ANNUAL CONVENTION, 1897.

Among the sources of energy available for industrial purposes, natural water powers have long held an important place, although the localities in which they could be made available have, until lately, been few in number. Within the past few years, however, the progress made in the methods for converting mechanical into electric energy, and the increase in the distance to which the latter can be economically transmitted, have led to the utilization of many water powers which were previously inaccessible. The advantages to any community of cheap and reliable power are so great that a steady growth of enterprises of this kind may be expected. Apart from manufactures of all kinds, the purely municipal purposes of lighting and electric traction will of themselves absorb a considerable amount of power.

It is proposed in the following paper to describe the works recently built in the cañon of the Ogden River, near the city of Ogden, by the Pioneer Electric Power Company of Utah, which constitute the latest

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions.*

and most important hydraulic power plant of that State, and one of the largest works of the kind yet undertaken in this country. In working out the details of this plant, the author derived much assistance from the experiences of others, as recorded in the *Transactions* of this Society as well as in other publications. He ventures to hope, therefore, that even an incomplete account of the designs and methods of construction adopted by the engineers of the above work may not prove without value in the planning of similar undertakings.

Location and Topography.—The city of Ogden is situated in the basin of Great Salt Lake, at an elevation of 4 300 ft. above sea level. It is about 13 miles east of that body of water, and 35 miles north of Salt Lake City. The limits of the city extend eastward to the base of the Wahsatch Mountains, which tower 5 000 ft. higher, reaching a total altitude of fully 9 000 ft. above sea level. This chain of mountains is intersected by numerous deep valleys or cañons, some of which rise abruptly, while others have a more gentle slope and form the outlet for drainage areas of considerable extent. Two such cañons, those of the Weber and Bear Rivers, are situated a few miles to the south and north of the city respectively, and are occupied by the Union Pacific and Utah Northern Railroads.

The cañon of the Ogden River is intermediate between the two last-named valleys, its outlet being directly east of Ogden and distant about 2 miles from the business center. It is a narrow, winding gorge, walled in by high and precipitous mountains, and presents a succession of scenes of romantic beauty unsurpassed in any other portion of the Rockies. The cañon is nowhere more than a few hundred feet in width at the bottom, and at some points it is so narrow that the construction of the excellent macadamized road that traverses it involved considerable rock excavation.

At a point about 6 miles above its mouth the narrow gorge through which the river flows widens out into a noble valley, some 8 miles long and 4 miles wide, surrounded by an almost continuous mountain chain. This valley contains several villages and many well-cultivated farms, and is traversed by three streams which unite at the upper end of the cañon, to form the Ogden River. A reference to the map, Fig. 1, will show clearly the course of the three branches, one of which drains the northern part of the valley, while another emerges from the mountains east of the village of Huntsville, and the third bisects the main

range on the opposite side of the valley directly east of the head of the cañon.

The average annual rainfall in Ogden is 14 ins. In the Ogden Valley it has never been measured, but is probably twice as great. The drainage area is about 360 square miles. The flow of the river varies

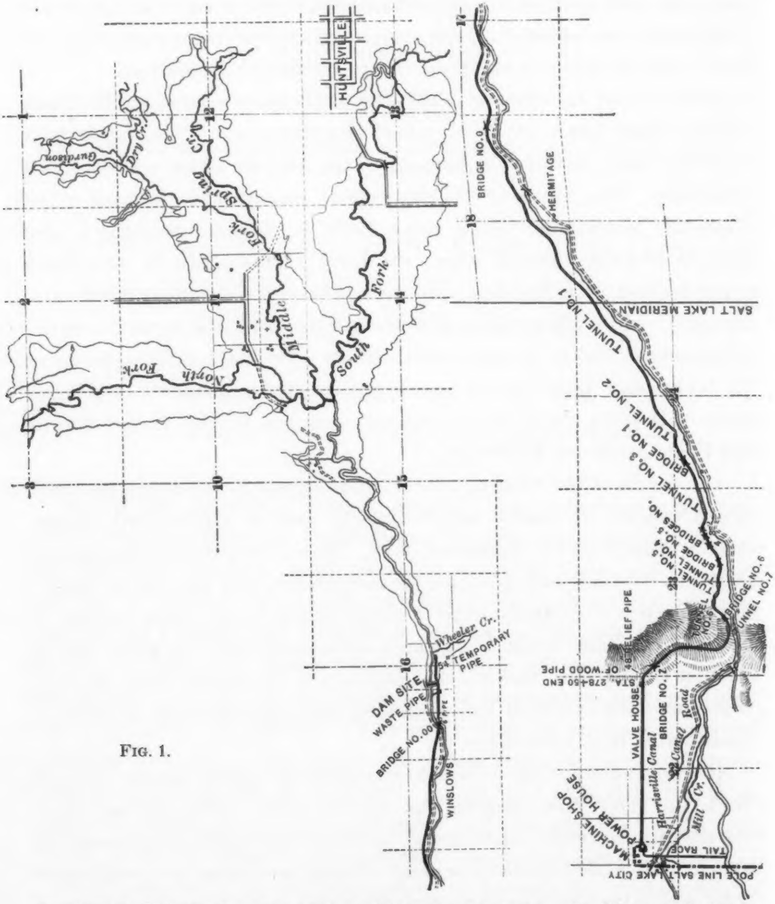

FIG. 1.

grealty in different years and at different seasons. In May and June, when the snow on the mountains melts, a maximum flow of 4 800 cu. ft. per second has been measured, while a minimum of 80 cu. ft. in August and September is also on record. The minimum in average years is fully 125 cu. ft. per second. In 1896 the flow did not go below 175 cu.

ft. per second. This refers to the flow in the river-bed near the dam site, but there is also considerable underflow in the gravel, as appears from the fact that the gauge readings several miles lower are always greater, though the affluents on this stretch are insignificant.

The slope of the stream in the upper valley is comparatively gradual, while in the 6 miles of the cañon there is a total fall of nearly 500 ft. This portion of the river has long appeared an attractive field for the development of power, but apart from a small saw-mill near its mouth there have been only abortive attempts made at utilizing the fall of the stream, and none of these earlier plants are now in operation.

The conception and successful completion of the works belonging to the Pioneer Electric Power Company are largely due to the efforts of C. K. Bannister, M. Am. Soc. C. E., who, as chief engineer and secretary of the company, has devoted several years to the careful study of the engineering and financial problems involved. Preliminary surveys were made in 1894 and 1895, but it was not until the beginning of of 1896 that the location of the plant was definitely settled and actual construction begun.

General Description of the Works.

The plans of the Pioneer Electric Power Company contemplate the utilization of the waters of the entire Ogden River water-shed above the mouth of the cañon for the development of power as well as for irrigation. The central features of the plant are : A large storage reservoir and a masonry dam at the upper end of the cañon; a pipe conduit 6 ft. in diameter ; a power house containing water-wheels and electric generators. Besides this, there are electric transmission lines and substations for distributing the power to different points, and an extended system of irrigation canals.

The Storage Reservoir.—This will cover an area of about 2 000 acres, and will have a capacity of nearly 15 000 000 000 galls. It will be formed by building a dam across the cañon a short distance below its upper end. Little clearing will be necessary, but a considerable amount of farm land will be submerged, and a number of houses and barns will have to be vacated. A number of miles of highway will also be covered by water, and it will be necessary to build a wagon road of equivalent length on each side of the reservoir. This will involve heavy rock excavation, and will be expensive in construction.

The Dam.—The dam will be built of concrete masonry and founded on the bed-rock. Its length, measured on the crest, will be about 400 ft. It will be about 60 ft. high above the present river-bed, and the foundation will extend about 40 ft. lower, making a total height of over 100 ft. The sides and bottom of the cañon, at the site of the dam, consist of solid limestone rock, but the bottom is overlaid to a depth of about 40 ft. with coarse gravel containing a large amount of groundwater. A spillway for carrying off the flood waters is to be built on the north side of the cañon. The dam and spillway are more fully described in a following section of the paper.

A 9-ft. tunnel has been excavated through the solid rock around the south abutment of the dam, which, at ordinary stages of the river, will be the sole outlet for the water in the reservoir. It is to connect at its upper end to a masonry inlet-tower, with six 60-in. ports and sluice gates for admitting water.

About 100 ft. below the tunnel, and connected to it by a riveted steel pipe 8 ft. 6 ins. in diameter, the main gate-house is placed. This building contains two 72-in. valves, one of which serves for discharging surplus water, while the other connects with the main conduit.

The Main Conduit.—The main conduit is a pipe line with an internal diameter of 6 ft. Its total length is 31 600 ft., of which 27 000 ft. consist of wooden stave pipe, while the last 4 600 ft., at the lower end is riveted steel pipe. It is laid in a trench 8½ ft. wide, and covered with earth to a depth of 3 ft. on top. The wooden pipe is located on the side of the cañon with maximum horizontal curves of 14° and vertical curves of 8°, and follows the side of the mountain to a point about half a mile beyond the mouth of the cañon. The hydraulic grade line is assumed to fall at the rate of 0.2 per hundred, and the wooden pipe is kept close to, but below, a gradient of this slope, which begins at low-water level in the reservoir. The upper portion of the wooden conduit is mainly in earth excavation, but towards the mouth of the cañon the trench was excavated almost entirely in limestone and granite rock. There are eight tunnels in the rock, the longest of which is 667 ft. There are also eight steel bridges, with a total length of 560 ft., besides a timber trestle. The maximum hydrostatic head on the wooden pipe will be 117 ft., giving a pressure of 50 lbs. per square inch.

The Steel Pipe.—Steel pipe is used at the lower end of the conduit for pressures exceeding that mentioned above. It extends from the lower end of the wooden pipe to the power house, following an alignment which is straight in plan, but is adapted to the contour of the ground by fourteen vertical angles. Between these points the pipe is straight, the elbows being formed with radii of 30 ft.

The steel pipe is of 6 ft. diameter till it reaches a point 100 ft. above the power house. Here it divides into two branches, 54 ins. in diameter, which lead to two large receivers, one on either side of the power house building. The total hydrostatic head from the flow-line of the reservoir, when it is full, to the center of the receivers will be 516 ft.

The Power House is built of pressed brick, with concrete and rubble footings, and cut-stone trimmings. Its outside dimensions are 135 ft. in length by 50 ft. in width. The roof trusses are of steel, and are supported on steel posts imbedded in the brick walls. The covering consists of standing seam steel roofing laid on a 2-in. sheeting of Douglas fir. A traveling crane of 15 tons capacity, operated by hand power, traverses the building, the track girders being carried by the steel posts. This building contains all the hydraulic and electric machinery used. A smaller, separate building serves as a machine and blacksmith shop.

Machinery.—The pipe line is calculated to deliver 250 cu.-ft. per second with a full reservoir, which corresponds to a velocity of flow in the 6-ft. pipe, of about 9 ft. per second. Taking the effective head at 440 ft., the gross available horse-power will be about 12 500.

The prime movers used are water-wheels of the impulse type, direct connected to electric generators. The complete plant will consist of ten water-wheels and dynamos, but only five are at present installed, although the power house building, the receivers, and the machine foundations, have been built in such a way that the whole number of machines can be erected at any time.

The water-wheels are of the Knight pattern, 58 ins. in diameter, with a capacity of 1 200 H.-P. each, at 300 revolutions per minute.

The dynamos are three-phase alternating-current generators. They give an output of 750 kilowatts at 300 revolutions per minute, and 2 300 volts continuously, with a frequency of 60 cycles per second.

There are two continuous-current exciters, direct connected with two 135-H.-P. water-wheels. Each exciter gives an output of 100 kilowatts at 550 revolutions per minute, and 500 volts continuously.

The arrangement of the wheels and generators is symmetrical on either side of the longitudinal axis of the building. There are two continuous foundations of concrete, and the central channel between them serves as a tail-race. After leaving the building, the water is carried back to the Ogden River by a channel, which is, in part, a covered flume, and partly an open ditch.

Of the machines at present installed, two of the wheels and generators are placed on one side, and three on the other. As the receivers, and in fact all portions of the plant, are in duplicate, the occurrence of an accident, which might cause a total stoppage of the plant, is almost wholly excluded.

In the gallery there are step-up transformers with a present capacity of about 3 000 H.-P. They receive the current from the generators at 2 300 volts, and raise the voltage to 16 100, at which pressure the current passes into the transmission lines.

The long-distance transmission lines are, at present, about 38 miles in length, extending to a substation in Salt Lake City. They deliver the current, at a voltage of 13 800, to the step-down transformers, which reduce it to 2 300 volts for local distribution. There are, besides this, wires for the local distribution of power in Ogden. The current in these lines has a voltage of 2 300.

The irrigation canals belonging to the company are situated near the shore of Great Salt Lake. The water from the pipe conduit, after leaving the power house, is allowed to run back into the natural bed of the stream, and is again taken out, at a point about five miles below, and diverted, so as to irrigate about 18 000 acres of land, not heretofore provided with water.

All portions of the plant are at present complete and ready for operation with the exception of the large dam and reservoir, the construction of which has not yet begun. A small crib dam with temporary headworks has been built a short distance above the site of the large dam, which gives the necessary head for filling the pipe, but does not provide for any considerable storage of water. A temporary stave pipe, 54 ins. in diameter, extends from the crib dam to the 9-ft. tunnel. In this way, the power plant can be operated and a consid-

erable amount of power generated prior to the construction of the large concrete dam.

Method of Doing Work.—The wooden and steel conduit was built by contract. The work done included not only the complete construction of all portions of the wooden and steel pipe line, but also all earth and rock excavation and tunnel work, as well as the masonry for bridges, culverts and retaining walls and the timber trestling. The steel bridges and the larger valves were purchased by the power company and erected by day labor. Smaller incidental work, such as the temporary headworks, etc., were built by day labor under the direction of the chief engineer, or let in small contracts. The power house and machine shop were built by contract, but the structural steel work was furnished by the company and the heavier girders erected by them. All the machinery was erected by the company by day labor, under the supervision of its engineers.

Detailed plans and specifications were made in the chief engineer's office of all parts of the work excepting the hydraulic and electric machinery, and the work of the different contractors was confined to carrying out the plans under the direction of the chief engineer and his assistants. In the case of the machinery, the specifications furnished to intending bidders gave the requirements and the general arrangement to which the designs would have to conform. They also included a statement of the tests to which the materials and the water-wheels and generators would be subject before acceptance. The detailed planning of the machinery was, however, left to the companies which made the tenders.

The Conduit, its Hydraulics and Construction.

The conduit consists approximately of 5 miles of wooden stave pipe and $\frac{7}{8}$ mile of riveted steel pipe. The former is everywhere $72\frac{1}{2}$ ins. in internal diameter, while the latter has an average internal diameter of $72\frac{1}{4}$ ins., but varies slightly at different points. As a 6-ft. steel pipe is from three to four times as expensive per lineal foot as a wooden pipe of the same size, economy prescribed a location by which the length of the metallic conduit should be reduced to a minimum. Besides this, the capacity of the smooth stave pipe is considerably greater than that of the steel pipe, so that, from hydraulic considerations, the use of wooden pipe is preferable. For both of these reasons the cheaper pipe is

used from the dam to a point close to the power house. Its location is such as to reduce the pressure that comes upon it as much as possible without increasing the excavation unduly. Hence the wooden pipe line is built to conform to a hydraulic grade line of 2 ft. per thousand, a slope which is believed to correspond to the friction in the pipe. A large amount of curvature is introduced, but the radii are large, so that the obstruction to the flow is probably inappreciable.

From the end of the wooden pipe, the steel conduit runs direct to the power house. The slope of the steel pipe is quite steep, and the pressure is from 50 to 200 lbs. per square inch.

For moderate diameters the choice between cast iron and riveted steel pipes will usually depend on local conditions. For a 6-ft. pipe under such heavy pressures and at so great a distance to the nearest pipe foundries, the use of cast iron was entirely out of the question. The objections raised against the use of riveted conduits are their greater liability to corrosion and their smaller capacity, owing to greater frictional resistance. In the Ogden pipe great care was taken to prevent the rusting of the plates in transit and at the shops, and a coating of asphalt was afterwards applied by which a long life for the pipe is believed to be fully assured.

As far as the capacity of the pipe is concerned, late experiments leave no room for doubt that a riveted pipe will convey considerably less water under a given head, than a pipe with an unbroken, smooth surface. Just how much less will depend on the nature of the construction and of the coating, the size of the pipe and the slope of the conduit. The recorded data for the flow of water in pipes exceeding 4 ft. in diameter are very scanty, even for smooth internal surfaces. For riveted conduits there are almost none in existence. Various formulas are in use for computing the frictional resistances for new cases as they arise. The best of these are confessedly empirical, merely combining in a convenient shape the results of a number of measurements. When applying them to novel conditions, the results can be only approximate, though the designing engineer must fall back on such inductions in determining the size of conduits differing from previous examples. It is a cherished hope of the projectors of the Ogden pipe that it may furnish an opportunity for a series of careful experiments which may throw additional light on the flow of water in large pipes.

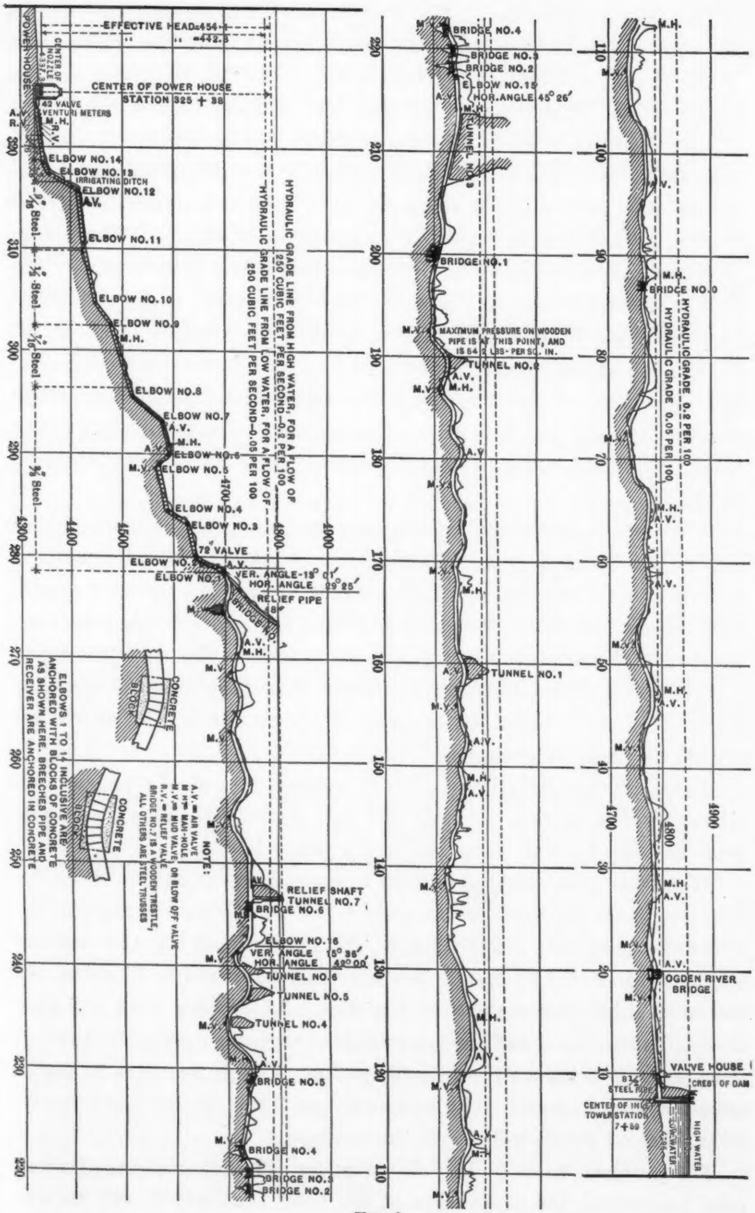

FIG. 2.

As appears from the profile (Fig. 2) and the preceding description, the Ogden conduit is compound, seven-eighths of its length being of wooden, and one-eighth of riveted steel, pipe. At the upper end the inlet will be funnel-shaped so that the coefficient at entrance will closely approach unity. The wooden pipe has an extremely smooth internal surface, absolutely without projections, and is continuous for its entire length, except at three points. These breaks consist of two riveted steel elbows and a short length of open tunnel. The elbows are of the same size and construction as the standard steel pipe. The radius of their central line is 30 ft., and the central angle about 45°. In Tunnel No. 7 the wooden pipe is omitted for a length of about 100 ft., and the unlined tunnel serves as a conduit. It is about 9 ft. square, and its surface is quite rough. The additional resistances at these three points will not, it is believed, absorb any considerable part of the head. The gate valves, when fully opened, will not obstruct the flow at all.

The surface of the steel pipe is very smooth, as the asphalt coating is glossy and continuous, with very few wrinkles. The obstructions to flow are the longitudinal internal butt straps and the rivet heads. The former are 16 ins. wide and $\frac{3}{8}$ in. and $\frac{1}{2}$ in. thick. They are continuous in almost all the sections, being exactly at the top of the pipe, so that they obstruct the flow much less than they would if breaking joint. The rivets have low, conical heads on the inside, which are smooth and regular in shape.

There are thirteen elbows of 30-ft. radius in the steel pipe, and one elbow of 40-ft. radius. From the end of the 6-ft. pipe, two $4\frac{1}{2}$-ft. branches about 100 ft. long lead to the power house.

If the 6-ft. pipe were open at its lower end, a straight line from the flow line in the reservoir to the end of the pipe would represent the hydraulic gradient. In that case, the greater part of the conduit would be above the hydraulic grade, so that air would be likely to collect at the high points and stop the flow. As actually used, the pipe is closed at its lower end, and the amount of water drawn off through the nozzles is comparatively small, so that a high pressure is maintained in the receivers. The hydraulic grade line, under these conditions, is at all points well above the conduit.

The problem, then, is to determine, for different amounts of water used per second, the proportion of the total head which will be ab-

sorbed by frictional resistances, and hence the pressure under which the water will be in the receiver at the lower end of the pipe.

The volume of water required to run the full plant of ten water-wheels will be 250 cu. ft. per second, which is equivalent to a velocity of $8\frac{3}{4}$ ft. per second in the 6-ft. pipe. The frictional resistances in the wooden and steel pipes for this velocity were computed separately and are given below.

Calculation of Friction Head.—If l is the length of pipe in feet, d is the internal diameter of pipe in feet, v is the velocity of flow in feet per second, g is 32.2, the acceleration of gravity, f is a coefficient that varies with d, v and the degree of roughness in the pipe surface, and h is the loss of head by friction, then

$$h^* = f \frac{l}{d} \frac{v^2}{2g}$$

In this case, for the wooden pipe, $l = 27\,000$ ft., $d = 6.03$ ft., $v =$ 8.75 ft. per second.

Then for the smooth wooden pipe, and the above values of d and v, f can be taken as 0.01, and for a length of 1 000 ft. of pipe—

$$h'' = 0.01 \frac{1\,000 \times 8.75^2}{6.03 \times 64.4} = 1.97 \text{ ft.}$$

Hence the virtual slope of 2 ft. per 1 000, to which the wooden pipe is laid, will be sufficient.

In the Chézy formula, $v = c\sqrt{rs.}$ The preceding result is equivalent to a value of

$$c = \frac{v}{\sqrt{rs}} = \frac{8.75}{\sqrt{1.51 \times 0.00197}} = 160.$$

This agrees closely with the value given for smooth pipes, under the same conditions, by Hamilton Smith, Jr., M. Am. Soc. C. E.†

In the Ganguillet and Kutter formula

$$v = \frac{41.6 + \frac{1.811}{n} + \frac{0.00281}{s}}{l + \left(41.6 + \frac{0.00281}{s}\right)\frac{n}{\sqrt{r}}}\sqrt{rs}$$

the value $c = 160$ is equivalent to a coefficient of roughness $n = 0.0104$.

Using the preceding value for h'', the total loss from friction in the wooden pipe is found to be $h = 27000 \times 0.0197 = 53.19$ ft.

For the riveted steel pipe c in the Chézy formula may be safely taken at three-fourths the above value, or 120.

* Merriman's "Hydraulics," pp. 168–169.

† See his "Hydraulics." Table on p. 271.

The friction head in 1 000 lin. ft. of pipe will then be $h'' = 3.52$ ft., or, 16.19 ft. in 4 600 ft. of steel conduit.

For the whole pipe line the loss of head will be $53.19 + 16.19 = 69.38$ ft.

The difference in elevation between the flow line in the full reservoir and the center of the receiver is 516 ft., hence the efficient head is $516 - 69.4 = 446.6$ ft. This must be slightly reduced to allow for the Venturi meters and other specials.

Steel Pipe Construction.—The steel pipe conduit extends from the lower end of the wooden pipe at station 278 + 50 to the power house. Of this length, about 4 600 consists of 6-ft. pipe and the remainder of

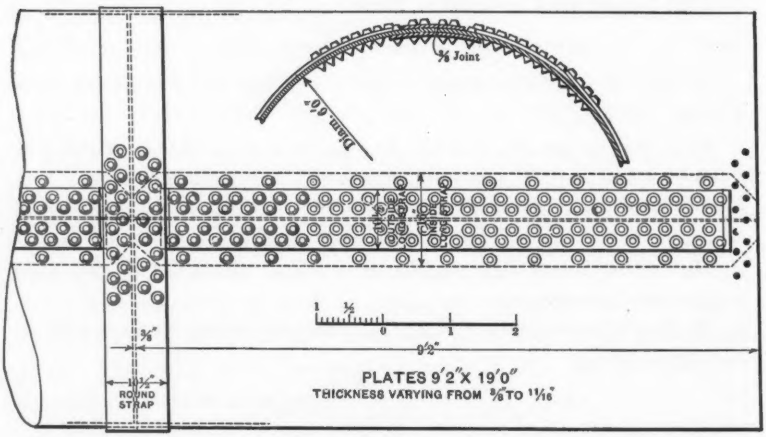

FIG. 3.

$4\frac{1}{2}$-ft. pipe, besides the receivers at the power house, which are merely sections of 6-ft. pipe of somewhat greater strength.

The profile is shown in Fig. 2, the alignment being a tangent from end to end. At the fourteen vertical angles the change of direction is made by means of elbows. The hydrostatic pressures in the pipe vary from 45 lbs. per square inch, where it joins the wooden pipe, to a maximum of 200 lbs. per square inch at the lower end. The size of the plates is the same throughout the straight part of the pipe, viz., 110 x 228 ins., giving sections 9 ft. 2 ins. long lengthwise of the conduit. There are 480 of such plates besides those used in the elbows. The thickness varies from $\frac{3}{8}$ to $\frac{11}{16}$ in., with increments of $\frac{1}{16}$ in., but the receivers are built of $\frac{7}{8}$-in. plate.

The internal diameter varies slightly with the thickness of the plates, which are uniformly 228 ins. long with $\frac{3}{8}$-in. joints.

Assuming the circumference at the middle of the thickness of each plate equal to 228.375 ins., which agrees closely with actual measurements, there results:

For	$\frac{3}{8}$-in. metal	an internal	diameter	of	72.32 ins.
"	$\frac{7}{16}$-in.	"	"	"	72.26 "
"	$\frac{1}{2}$-in.	"	"	"	72.19 "
"	$\frac{9}{16}$-in.	"	"	"	72.13 "
"	$\frac{5}{8}$-in.	"	"	"	72.07 "
"	$\frac{11}{16}$-in.	"	"	"	72.01 "

or an average diameter of 72.22 ins., if the lengths of conduit which are built of plates of different thicknesses are taken into account.

The construction of the pipes follows the usual practice of marine boiler work for high pressures. It is shown in Fig. 3. Extracts from the specifications are given in Appendix A.

The specifications for the steel were fully complied with, and the finish of the plates left nothing to be desired. The clause in the specifications limiting the excess in weights to 5% above the calculated weight, while requiring the plate to be practically of full thickness even at the edges, was doubtless too severe. In making these wide plates, the inevitable springing of the rolls made it impossible to keep the excess in weight down to the close limits permitted.

Another point in the specifications may be referred to, namely, the clause which requires that test pieces cut from finished plates of different thicknesses must show the same strength and ductility. While in this requirement the common practice of the past few years is followed, it is doubtful in the author's opinion whether it can be successfully defended. A tensile strength of 60 000 lbs. per square inch, with an elongation of 24% in 8 ins., corresponds in a plate $\frac{3}{8}$ in. thick to a carbon percentage of about 0.15, if basic open-hearth steel is used with phosphorus and manganese as specified. To obtain the same tensile strength and ductility in the $\frac{3}{4}$-in. plate rolled down from slabs or ingots of the same size, it is necessary to increase the carbon to fully 0.24. This means, of course, a much harder steel, which will be more subject to injury in subsequent processes of manufacture. The "rolling" of plates into cylindrical pipes causes severe strains in the metal, and experience has proved that much greater care is required in getting a perfect result in the thicker sheets. For this reason it

would be desirable to modify the specifications for plates so as to provide that the tensile strength required in the thicker plates should be less than in the thin ones. The chemical composition of the steel would then be more nearly the same, and the capacity of the heavier gauges for standing the necessary strains in the boiler shop would be increased.

Strength of the Riveted Steel Pipe.—The principal strain to which a water-pipe conduit is subjected is that due to internal fluid pressure. For pipes in which the ratio of the diameter to the thickness of the metal is considerable, this strain is given correctly by the simple formula of Mariotte. For pipes closed at the ends, there is a longitudinal strain in the plates composing the conduit. In any given case this unit strain will be only half as great as that which tends to burst the pipe. In a pipe bedded in earth this force is absorbed by friction, and its effect on the metal probably extends only a short distance from the closed end.

Differences in temperature and an unequal settlement of the conduit may also develop strains of considerable amount, which must be borne in mind when fixing the details of construction. Even more important is the possible action of collapsing strains, due to external air pressure, which may occur if the pipe is suddenly emptied by accident. It is hardly feasible to build a pipe of large diameter to withstand an external strain of this kind unless ample provision is made for admitting the outside air and preventing the formation of a vacuum. In the Ogden pipe a large number of valves and relief shafts are provided for this purpose, which are described in detail in a following section of the paper.

In fixing the thicknesses of the plates and the points on the profile at which they change, the unit strains on the gross section were taken at 12 000 lbs. per square inch in the $\frac{3}{8}$-in. sheets, decreasing to 11 000 lbs. for the $\frac{11}{16}$-in. plates.

The greatest head, h, to which any given thickness of plate was subjected, is shown in the following table :

$\frac{3}{8}$-in.	plate,	gross	strain	12 000 lbs.	per	square	inch,	$h = 288$ ft.
$\frac{7}{16}$-in.	"	"	"	11 800	"	"	"	$h = 330$ "
$\frac{1}{2}$-in.	"	"	"	11 600	"	"	"	$h = 371$ "
$\frac{9}{16}$-in.	"	"	"	11 400	"	"	"	$h = 410$ "
$\frac{5}{8}$-in.	"	"	"	11 200	"	"	"	$h = 448$ "
$\frac{11}{16}$-in.	"	"	"	11 000	"	"	"	$h = 484$ "

The net strains in the plates, the rivet stresses and the efficiency of the joints, that is, the ratio of the strength of the joint to that of the unpunched plate, are given below. The calculations will be understood better by referring to the details of the riveting shown in Fig. 3. The net section is taken between the rivet holes in the outer row of rivets, the pitch of which is twice as great as that in the other rows.

Triple Riveting, Zigzag; Double Pitch in Inside Row.

Plate, $\frac{11}{16}$ in. Rivets, $1\frac{1}{8}$ ins., cold; $1\frac{3}{16}$ ins., upset. Pitch, $3\frac{7}{8}$ ins.

Maximum tensile stress on plates, gross section....11 000 lbs. per square inch.
" " " net section......12 940 " " "
" shearing stress on rivets................. 5 740 " " "
" bearing " ....14 600 " " "
Efficiency of joint, 85 per cent.

Plate, $\frac{5}{8}$-in. Rivets, $1\frac{1}{8}$ ins., cold ; $1\frac{3}{16}$ ins., upset. Pitch, $3\frac{7}{8}$ ins.

Maximum tensile stress on plates, gross section....11 200 lbs. per square inch.
" " " " net section.......13 200 " " "
" shearing stress on rivets .... 5 200 " " "
" bearing " " ....14 800 " " "
Efficiency of joint, 85 per cent.

Plate, $\frac{9}{16}$ in. Rivets, 1 in., cold; $1\frac{1}{16}$ ins., upset. Pitch, $3\frac{7}{8}$ ins.

Maximum tensile stress on plates, gross section....11 400 lbs. per square inch.
" " " " net section.......13 200 " " "
" shearing stress on rivets................. 5 520 " " "
" bearing " " ....15 800 " " "
Efficiency of joints, 86.2 per cent.

Plate, $\frac{1}{2}$ in. Rivets, 1 in., cold; $1\frac{1}{16}$ ins., upset. Pitch, $3\frac{9}{16}$ ins.

Maximum tensile stress on plates, gross section....11 600 lbs. per square inch.
" " " " net section.......13 600 " " "
" shearing stress on rivets................. 5 200 " " "
" bearing " " ....16 400 " " "
Efficiency of joint, 85.2 per cent.

Plate, $\frac{7}{16}$ in. Rivets, $\frac{7}{8}$ in., cold; $\frac{15}{16}$ in., upset. Pitch, $3\frac{9}{16}$-ins.

Maximum tensile stress on plates, gross section....11 800 lbs. per square inch.
" " " " net section.......13 500 " " "
" shearing stress on rivets................. 5 020 " " "
" bearing " " ....15 200 " " "
Efficiency of joint, 87 per cent.

Plate, $\frac{3}{8}$ in. Rivets, $\frac{7}{8}$ in., cold; $\frac{15}{16}$ in., upset. Pitch, $3\frac{9}{16}$ ins.

Maximum tensile stress on plates, gross section....12 000 lbs. per square inch.
" " " " net section.......14 000 " " "
" shearing stress on rivets................. 4 300 " " "
" bearing " " ....15 200 " " "
Efficiency of joint, 87 per cent.

Construction of Elbows.—The thickness of the plates in the elbows is the same as in adjacent straight sections. The change of direction between successive sections of an elbow was limited to 4° or 5°, so that each section is about 2½ or 3 ft. long. The maximum angle of any elbow was 45°, requiring nine or ten elbow sections. The butt straps, sizes of rivets and rivet spacing are the same as for straight pipe. Detailed drawings of all elbow plates were made in the chief engineer's office, by which all work in the shop was done.

Method of Construction.—All the work connected with the construction of the steel pipe sections was done at Ogden in a shop especially built and equipped with machinery for the purpose by the contractors. The principal reasons for adopting this plan were, first, the great saving in freight charges which resulted from being able to ship flat plates up to the full capacity of the cars instead of the finished pipe sections of which, for the lighter gauges, hardly half a carload could have been loaded on a standard flat car, and, second, that both work and inspection might be under the personal supervision of the chief engineer and his assistant on the pipe line. The contractor's works were erected near the lower end of the steel pipe line, on a spur track 3 miles in length, laid by the Union Pacific Railroad to connect with its main line. The boiler shop was a substantial frame building, covered with corrugated sheeting; it was 175 ft. long and 45 ft. wide, with a lean-to 40 ft. in width on each side. The railroad track passed through the building at one end and all material was unloaded under cover by a traveling crane which ran from end to end of the building, and, with several small jib-cranes, served to handle the work at the different machines. This crane was of 5 tons capacity; the traversing machinery was operated by electricity, while air hoists were used for lifting.

This building contained all the machinery required for punching, rolling, riveting and calking the pipe sections, and also the air compressor by which the field riveting and calking machines in the trench were driven. Two punches which were also used for shearing, a steam riveter, a set of 12-in. plate rolls, 120 ins. in length, and a 14-ft. planer for finishing the edges of plates and straps, constitute the larger machines installed. Besides this, there were three drilling machines, especially mounted for reaming rivet-holes, and some smaller shaping machines and lathes. Adjoining the main shop, a

blacksmith's shop, enclosed with corrugated iron, was built, in which the usual forges and furnaces for heating the rivets were placed, so as to reduce the fire risk of the larger and more inflammable building.

The construction of the shop was begun about May 15th, 1896, but there was some delay in the delivery of machinery so that the first plate was not punched till the middle of July. After this time until nearly the end of the year, work was pushed with two shifts of men, night and day and seven days in every week. It may be mentioned, in passing, that in September a violent wind storm overturned the main building, but fortunately did little damage to the machinery, so that the work was delayed only a few days.

The methods used were those of first-class boiler shops, and the work turned out compared favorably with the product of well-equipped eastern works. While it was not intended to increase the cost of the pipes unduly, the inspection was continuous and severe. The planing of butt straps and the reaming of the holes for $1\frac{1}{8}$-in. rivets, as required by the specifications, were strictly insisted upon, and the fitting was, as a rule, extremely good. The sections were riveted up complete in lengths of 9 ft. 2 ins., with a round-about strap riveted fast to one end, so that the field work was confined to making the connection between adjoining sections. The steam riveter used in the shop formed the heads by direct pressure and gave very good results. It was necessary, however, especially with $1\frac{1}{8}$-in. rivets, to hold on until the rivet head had cooled to a black heat.

Great care was taken with the calking of the joints. It was done entirely on the outside straps by the use of split calking machines driven by compressed air. The calking was generally done while the section was suspended above the riveter, so that the outer row of rivets in the longitudinal butt-straps could be driven after the calking was finished. The calking of one edge of the round straps had, of course, to be done after the pipe was laid in the trench.

Dipping of the Pipe.—As soon as a section was completed, it was taken to the dipping tank adjoining the shop, which was equipped with a revolving derrick moved by steam power. The tank was circular, made of $\frac{1}{4}$-in. steel plates, and buried entirely below the ground. The mixture used consisted of C grade California asphalt, with the interstices filled with the best quality of natural liquid asphalt maltha,

not above 14° gravity Beaumé test. The mixture was melted and kept at a proper temperature by steam coils in the tank. It was found that a prolonged process of coating gave the best results, and for this reason nearly an hour was consumed in dipping each section, and gradually withdrawing it from the boiling mixture. The coating was smooth and glossy, and stood the necessary handling without much damage.

Erection and Riveting of the Steel Pipe in the Trench.—The riveting of a steel pipe line of the diameter and length of the Ogden pipe in the short period of time to which the contractor was limited presented many difficulties. For the $1\frac{1}{8}$-in. and even 1-in. rivets hand work was not practicable, and it was undesirable even for the $\frac{7}{8}$-in. rivets. Power riveters for this class of field work were almost if not quite untried, and there was little time for experiments. Two forms of power riveters were specially designed for the work, and all the rivets were driven with them, there being practically no hand riveting on any part of the pipe. They were both operated by compressed air which was drawn from a small pipe laid down on the edge of the trench for the entire length of the steel conduit. This pipe was 3 ins. in diameter where it left the compressor in the boiler shop, decreasing to 2 ins. at the upper end. The pressure used varied from 50 to 75 lbs. per square inch.

The first type of machine adopted by the contractors and used exclusively in the earlier stages of the work was designed by George H. Pegram, M. Am. Soc. C. E. The parts of the machine in the inside and on the outside of the pipe are entirely distinct. The former consists of a pressure cylinder and piston, the axis of which coincides with the central line of the pipe, and a framework with a toggle-joint. By means of this the thrust of the piston is turned through 90°, so as to form the heads of two rivets diametrically opposite each other on the inside of the pipe. The cylinder revolves freely on its axis and can be rotated so as to drive in succession all the rivets in a given row. It is supported by means of springs on a low iron truck with wheels, running on a short track which rests on the bottom of the pipe. This machine acts by direct pressure like the steam riveting machines commonly used in boiler and bridge shops.

The portion of this machine outside of the pipe consists essentially of a heavy cast-steel ring which furnishes the necessary reaction against

the thrust of the riveting machine inside. For this purpose four cups, adjusted by means of hand-wheels, are attached to the large ring at points 90° apart. The ring hangs from a framework above, which travels on a timber runway supported on the top of the pipe. Gearing is provided for traversing the entire frame, as well as for revolving the ring around the axis of the pipe. When in operation, two rivets are inserted from the outside into holes diametrically opposite; the ring is moved so that two of the cups come exactly opposite the rivets. The hand-wheels are then screwed down and pressure is applied from the cylinder within. All the rivets in a row are driven with one setting, but when a joint is completed the entire machine must be moved ahead, which, for so heavy an apparatus, is rather slow work. About 500 rivets have been driven in a day of ten hours with this machine.

The second type of riveting machine used is much lighter than the one last described. The heads are not formed by steady pressure, but by striking a large number of blows in rapid succession. A frame work encircles the pipe and sustains the internal reaction; it revolves on the pipe on special cast rollers. One rivet only is driven at a time, the head of which is formed on the inside of the pipe. There is an air cylinder with a piston which is moved forward after the rivet is inserted, so as to hold it in place and sustain the blows of the percussion riveter within the pipe. The latter is comparatively light so that it can be handled by only two men working inside of the pipe. It consists of a small air cylinder, similar to that of a percussion rock-drill, the piston-rod of which has a cup at its outer end. This contrivance is held in place by a heavy rod, fastened into a rivet hole diametrically opposite the rivet to be driven.

The operation is similar to that of the Pegram riveter, and the number of rivets driven per day is about the same. Owing to its greater lightness, the number of men required to handle this machine is considerably less, thus reducing the cost of driving a rivet.

The quality of the work appears to be entirely satisfactory, although for driving the $1\frac{1}{8}$-in. rivets, in the $\frac{11}{16}$-in. plates, a somewhat heavier machine would be preferable.

Erection.—The trench in which the steel pipe was laid was almost everywhere accessible by team, and the sections were distributed in this way. At convenient points, a number of lengths were unloaded

and a sloping runway cut out, along which the sections were skidded into the ditch. A short length of light railroad track was commonly built along the center of the trench on which the sections were transported to connect with the finished ends.

The riveting machines used made it necessary to excavate below the pipe to an additional depth of about 3 ft. so as to allow the framework of the riveter to pass. The sections were supported on timber blocking placed from 5 to 9 ft. apart. This blocking consisted of 6 x 6-in. timbers, from three to six pieces being laid one on top of the other. The engineer's grade stakes were generally set with their tops a multiple of 6 ins. below the bottom of the pipe, so that the foreman knew just how many timbers were needed at any point to give correct grade.

The joining of the sections was readily made and the practice was to keep the erecting gang a number of sections ahead of the riveting machines, so that both riveting and erection could proceed uninterruptedly. At the beginning of the work much difficulty was met with in building the pipe to a straight line, as it showed a decided tendency to assume a vertical curve which threatened to bring the pipe to the center of the earth instead of the top of the hill side. The exact cause of this distressing phenomenon was the subject of much discussion, but was never fully settled. As a matter of fact, after the men became more experienced and greater care was taken with the blocking, the difficulty disappeared, and the foreman finally became quite expert in giving the pipe any desired elevation or direction. The elbows and tangents fitted the ground almost perfectly, and of about 500 plates ordered not a single one was spoiled, either in the shop or field.

Testing the Pipe.—When the first ten sections of $\frac{11}{16}$-in. pipe were riveted up in the trench, making a total of 92 ft. of completed pipe, they were closed at each end by dished heads, which were bolted fast and calked with lead. The pipes were filled with water and subjected to hydraulic pressure. For this purpose the air compressor was speeded up so as to give a pressure of 200 lbs. per square inch, which was maintained for twelve minutes, when it was stopped from fear of injuring the rather light compressor used. While the compressor was at work, the pressure was raised to 250 lbs. per square inch at intervals by a hand-pump. This last increment of pressure was applied as a jerk or kind of water-hammer, so that as a test it was doubly severe.

Under this pressure the pipe proved to be very tight. Out of some 3 000 rivets, only twenty-two were discovered that leaked at all, and most of these merely sweated. The calked joints were also practically tight, showing only a few slight leaks. These sections were the first built. The latter work would probably, if tested in like manner, have given even better results.

Anchorages.—The profile of the steel pipe line shows that it contains some steep grades. It was deemed advisable to hold the pipe at these places by building anchorages around it at the angle points. These anchorages consist of concrete blocks, about 8 x 10 ft. in section and about 10 ft. long. They were built in timber molds. The mixture consisted generally of Portland cement, sand and crushed stone, in the proportions one, two and five.

Back-Filling.—It was originally intended not to cover up the steel pipe until after it was completed and filled with water, but as the work progressed it was found that the effect of the differences in temperature made it desirable to put in the back-filling sooner. The earth was, therefore, shoveled under and around the pipe, filling the trenches and covering the pipe about 3 ft. on the top. The filling was, of course, carefully tamped. The effect of temperature on the pipe was twofold. When there was bright sunshine on the top of the pipe, the bottom remaining in the shade, the exposed side was elongated, so that the pipe line became curved, and in one case was observed to lift from its supports for a distance of over 100 ft.; besides this, there was considerable expansion and contraction longitudinally, as well as a change in the diameter of the pipe. As a consequence, the pipe shrank away from the concrete in the anchorages, leaving openings which, in some cases, were as large as half an inch. Several of the concrete anchorages also showed a number of fissures and cracks, both on top and on their sides.

Weights and Lengths of Steel Pipe.—There are 476 regular sections of straight 6-ft. pipe, besides the 14 elbows. The lengths and weights are given in Table No. 1, calculated on a basis of 490 lbs. per cubic foot. The invoice weights were about 6% greater.

Wooden Stave Pipe.—The wooden stave pipe is of the type successfully used in the West for many years. It is believed, however, that its diameter of 6 ft. is greater than that of any conduit of the kind previously built. A new departure, too, is the use of Douglas fir in

place of California redwood. The former timber is much harder and stiffer, and some trouble was anticipated in its use for staves, especially in view of the great amount of curvature in the pipe line. After the first few days, however, no great difficulty was experienced in putting the staves together properly, even on the 14° curves.

The lumber was furnished by Oregon and Washington mills, being planed on all sides to a uniform finished size of 8 x $2\frac{1}{2}$ ins. before shipment. The specification was a severe one, requiring the best class of timber, perfectly free from knots, sap holes, season-checks and other flaws. It was carefully inspected at the mills, and again after delivery

TABLE No. 1.—Weight of Steel Pipe. Pounds.

Number of sections.	Thickness of plate. Inches.	Length. Feet.	Weight of main plates.	Weight of longitudinal straps.	Weight of roundabout straps.	Total weight, plates and straps.	Weight of rivets.	Grand total.	Weight per lineal foot.
186...	$\frac{3}{8}$	1 711.2	495 876	57 846	52 200	605 922	45 019	650 941	380
66...	$\frac{7}{16}$	607.2	205 260	20 526	21 600	247 386	16 415	263 801	434
79...	$\frac{1}{2}$	726.8	280 766	24 569	29 550	334 885	29 120	364 005	500
70...	$\frac{9}{16}$	644.0	280 000	21 770	29 430	331 200	24 275	355 475	552
29...	$\frac{5}{8}$	266.8	128 818	12 006	13 560	154 384	14 184	168 568	632
46...	$\frac{11}{16}$	423.2	224 620	19 044	25 180	268 844	23 637	292 481	691
476...	....	4 379.2	1 615 340	15 761	171 520	1 942 621	152 650	2 095 271	478
Divided as follows:				Main plates,	77%	or 100%			
				Straps,	15%	20%			
				Rivets,	8%	9%			
					100%	129%			
14 elbows in 6-ft. pipe.			71 231	6 144	17 628	95 003	11 593	106 596	

The $8\frac{1}{2}$-ft. pipe near the dam, the $4\frac{1}{2}$-ft. pipe at the power house, and the receivers raised the total weight of the steel pipe to over 2 500 000 lbs.

at Ogden. The lumber used was almost beyond criticism, being practically perfect in appearance. It was, as far as possible, thorougly seasoned and dried and was kept under cover at Ogden until it was placed in the trench.

The pipe was built of thirty-two staves, the finished staves being $7\frac{1}{2}$ ins. wide on the outside, $7\frac{1}{8}$ ins. wide on the inside, and 2 ins. in thickness. A planing mill for the work of building the wooden pipe was especially erected near the mouth of Ogden Cañon. In this mill both sides of the staves were dressed in a planing machine to conform to the outlines of a circle; the outside to a circle of $38\frac{1}{4}$ ins. radius, and the inside to a circle of $36\frac{1}{4}$ ins. radius.

The radial surfaces were planes, smoothly finished. Steel templets of the stave section were furnished to the contractor and the inspectors, and no stave varying more than $\frac{1}{32}$ in. was accepted.

According to the specifications, the length of staves were to be 16, 18, and 20 ft., but no more than 15% of 16-ft. lengths, nor more than 30% of 18-ft. lengths, were allowed. This condition was fully complied with, and many lengths of 24 ft., 26 ft., and even more, were used.

In building the pipe the staves were selected so as to break joints at least 12 ins., and at all end joints a steel tongue was placed, being fitted into grooves sawed into the ends of the staves. These grooves had a depth equal to half the width of the tongue, and were of such width that the tongues fitted tightly. The tongues were $1\frac{1}{2}$ ins. wide, about $\frac{1}{8}$ in. thick, and somewhat longer than the width of the staves, so as to extend $\frac{1}{8}$ in. into the two adjoining staves. Experience in previous conduits has shown that this construction is sufficient to make a tight joint at the ends of staves. The radial edges of the staves are perfectly plain, without the beading sometimes used, dependence being placed on the swelling of the timber for producing a tight joint.

Sills.—At intervals of 8 ft. throughout the length of the conduit, sills 6 x 8 ins. and 8 ft. long were laid in the trench with the 8-in. side down, at right angles to the center line of the pipe, with chocks cut to fit the periphery of the pipe at each side and fastened on top of each sill by a boat spike. An additional brace of 2 x 4-in. timber was placed at an angle of 45°, and also spiked to the sill. These sills were bedded as exactly as possible, according to the engineer's lines and grades, and proved a sufficient guide for placing the pipe in its proper position.

Bands.—Many different methods for banding stave pipe have been proposed from time to time, but only a few of them have had the test of practical experience. In the early pipe lines, bands similar to those used on barrels were employed, but the use of round rods of steel has now become universal for all but the smallest sizes. There are, however, many different forms and details for connecting the rods and making the necessary adjustments.

On the Ogden pipe the bands consist of round steel rods of $\frac{5}{8}$-in. and $\frac{3}{4}$-in. diameter, the latter being used only where the pressure exceeds that due to a head of 100 ft. They were made of tested steel, having an ultimate strength in tension of between 55 000 and 65 000

lbs. per square inch, an elastic limit of 40 000 lbs. per square inch, and an elongation of 25% in 8 ins. The percentage of phosphorus was not to exceed 0.095, and of sulphur 0.075. Each rod was to bend cold through 180° upon itself without sign of fracture.

A complete band consists of two rods bent to a semi-circle and two steel shoes. Their shapes and sizes are represented in Fig. 4. There are two kinds of rods, one of each kind being required to make a complete ring or band. The first kind has a loop eye at each end and was made of one piece of steel without welds, except in the loops. The

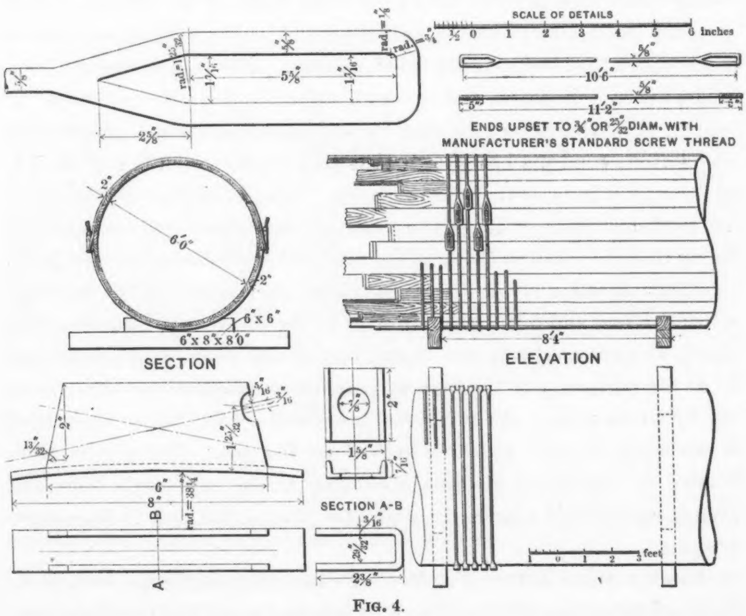

FIG. 4.

second kind of rod has two upset screw ends made without welding. All nuts were at least ⅞ in. thick, and of such close fit that with clean threads they could not be turned with the finger. The shoes are also shown in Fig. 4, together with the method of adjusting the rods and shoes. They were pressed when hot out of $\frac{3}{16}$-in. steel and have proved quite satisfactory during the construction of the pipe, though a slight increase of the thickness of metal would probably be an improvement. The form of shoe and rods was designed by Mr. J. C. O'Melveny, of Ogden.

The bands are placed perpendicular to the end of the pipe with the shoes at the sides and spaced according to the instructions of the engineer. It was desired to subject the bands, as far as possible, to the same maximum unit strain in all portions of the conduit. For this purpose a table was prepared giving the number of bands to be used in each 100 ft. of pipe and their average distance apart. Where there was much difference in the pressure within the limits of a 100-ft. section, the spacing was changed at the + 50 point, and in some cases a different spacing was used in every 25 ft. of length.

The working stress of a $\frac{5}{8}$-in. rod was taken at 4 500 lbs., and of a $\frac{3}{4}$-in. rod at 6 500 lbs., giving a unit strain of 14 660 lbs. per square inch of metal. The spacing was, of course, proportioned in accordance with the head at each point, the whole water pressure being supposed to be carried by the bands, as no allowance was made for any stiffness of the staves.

The following simple formula was used in the computations, the diameter of the pipe being taken as 6 ft., in which H is the effective head in feet at any point, N is the number of bands required for a length of 100 ft.

$$\text{Then, for } \tfrac{5}{8}\text{-in. bands, } N = \frac{H \times 62.5 \times 6 \times 100}{4\,500 \times 2} = 4.16\,H$$

$$\text{and for } \tfrac{3}{4}\text{-in. bands, } N = \frac{H \times 62.5 \times 6 \times 100}{6\,500 \times 2} = 2.9\,H$$

When the reservoir is full, the least static head on any point of the wooden pipe will be 55 ft. and the greatest 117 ft. Five-eighths-inch bands are used for heads up to 100 ft., and $\frac{3}{4}$-in. bands for greater pressures. The spacing for the $\frac{5}{8}$-in. bands varies from $5\frac{1}{4}$ down to $2\frac{7}{8}$ ins., changing by differences of a $\frac{1}{4}$ of an inch between $5\frac{1}{4}$ and 4 ins., and by differences of $\frac{1}{8}$ in. between 4 and $2\frac{7}{8}$ ins. The spacing of the $\frac{3}{4}$-in. bands is 4 ins. for 100 ft. head, which is gradually reduced by differences of $\frac{1}{8}$ in. to a minimum pitch of $3\frac{1}{2}$ ins. By this arrangement the strain on the metal comes within 3% of being the same on all the bands used.

The only other detail that calls for comment is the connection of the wooden and the steel pipes. As shown in Fig. 5 all parts are of rolled steel. The steel pipe enters into the stave pipe for a length of 12 ins., and is securely bolted. Besides this, there are two angle flanges, one of which is riveted to the steel pipe, while the other con-

sists of loose angle irons fastened by bolts. There is a packing of tarred burlap between the steel rings and the staves. Six connections of this kind are used in the main pipe, one each at the upper and lower ends, and the others at two points, where the alignment made it necessary to use steel elbows.

Erection.—The light weight of the separate staves and bands makes stave pipe specially adapted for cañon work. In the upper part of the valley, the line was easily reached with teams. Further down it is less accessible, and at the mouth of the cañon a cable-way about 1 000 ft. in length supported on framed towers, was built, by which a large amount of material was raised. The hoisting engine, the lifting capacity of which was about a ton, was placed at the bottom. The incline described later in connection with the bridge work also served

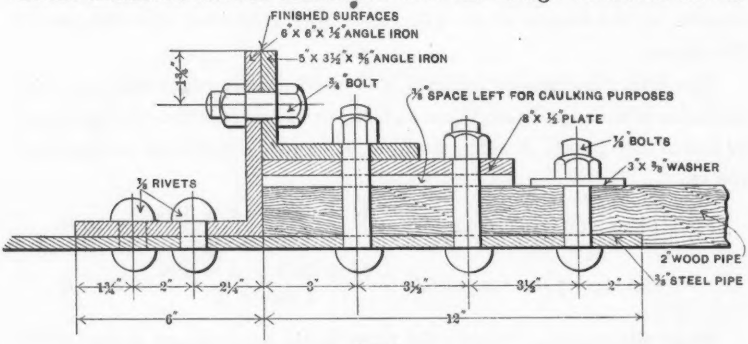

FIG. 5.

to take up pipe material. A light track, laid in the trench, was used for distributing the staves and bands.

The building of the pipe proceeded at a number of different points simultaneously, and at one time there were seven separate gangs at work, laying as much as 500 lin. ft. per day. In the lower portion it was not possible to work at more than two or three places. Each gang consisted of about twenty men; about half of these were engaged in putting the staves together, using only enough bands to keep the pipe in place. The rest of the men followed, and put on the full number of bands. They were cinched back afterwards several times with short wrenches, so as to obtain a proper amount of tension without crushing the fiber of the wood.

The vertical curvature was obtained by building the pipe on the sills, properly set beforehand, but where these were sharp, horizontal

curves, it was necessary to spring the partly banded pipe by means of jacks. It was then held in place by blocking, and, after being full banded, showed no tendency to return to a straight line. In assembling the staves, a bent piece of 2-in. pipe was used as a templet, but the vertical diameter was made slightly greater than the horizontal to allow for settlement.

The whole pipe, except the parts in the tunnels and on the bridges, was covered with earth to a depth of 3 ft.

The amount of lumber used was about 1 500 000 ft. B. M., and the total weight of steel in bands and shoes about 2 500 000 lbs.

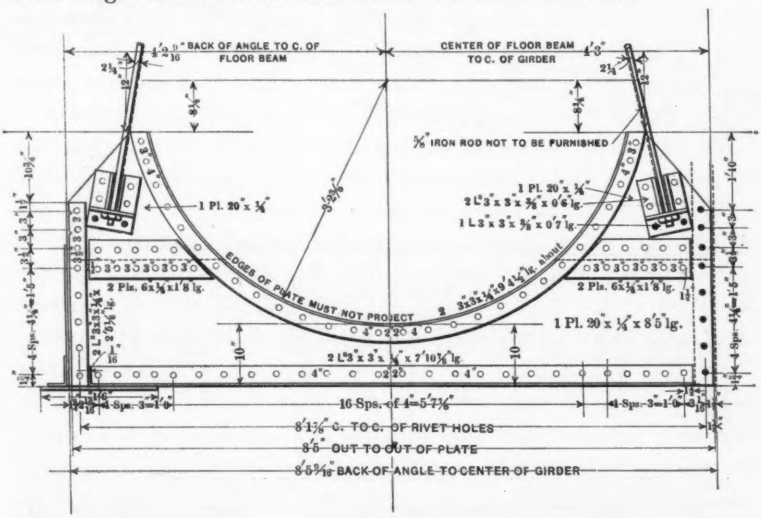

Fig. 6.

Bridges.—There are nine bridges on the line of the pipe line, of which one is a timber trestle, while the rest are built of steel. Besides these, all of which carry the wooden pipe, there are a few short culverts under both the wood and the steel pipes.

The longest span is the bridge which carries the pipe over the Ogden River, at the only place where the conduit crosses that stream. This bridge is a riveted bowstring girder 75 ft. in length. The top chord forms the segment of a circle, with a 75-ft. radius, while the lower chord is bent to an arc corresponding to a vertical curve of 6°. The floor beams are attached to verticals 4 ft. 3 ins. apart. The distance between centers of girders is 8 ft. 6 ins.

The other bridges carry the pipe line over lateral ravines, or else were built in place of masonry retaining walls at points where a steel structure was cheaper. They are all riveted girders with a single Warren system of bracing and vertical end posts. The floor beams are shown in detail in Fig. 6. They are fastened to vertical angles at every 4 or 5 ft., so as to support the stave pipe at frequent intervals. The distance between girders is 8 ft. 6 ins. throughout.

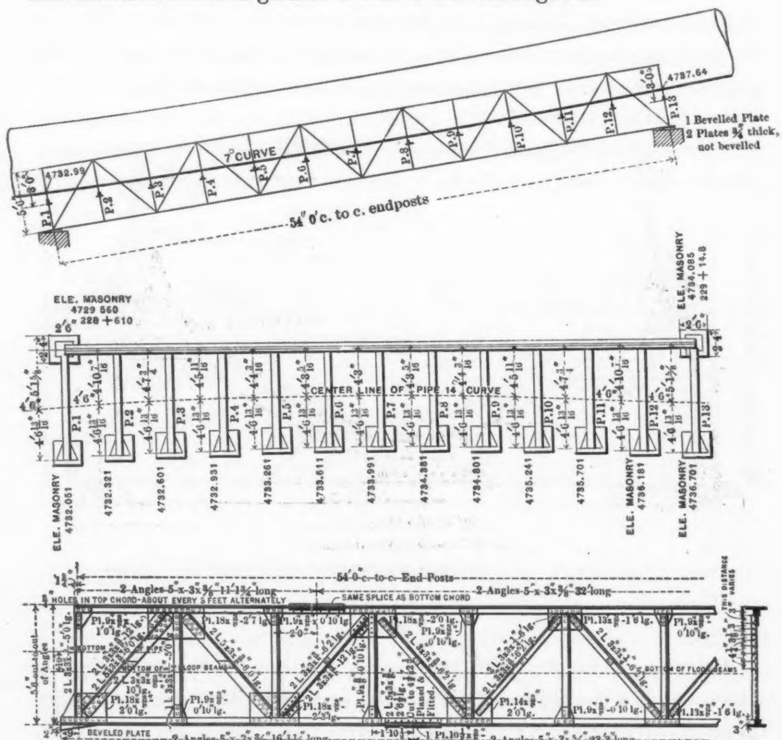

FIG. 7.

Bridges 2, 3, 4 and 6 consist of two girders supported on masonry abutments. The only interesting feature in their construction arises from the fact that the pipe line is built with vertical curvature, so that the floor beams had to be placed at different elevations. The tops of the abutments were therefore placed at such an elevation that a straight line connecting the bed plates is parallel to the chord of the vertical arc. The offsets from this chord were then computed for

every floor beam, and the position of the connecting bolt holes in each vertical post of the girders determined accordingly. The floor beams themselves remained the same for these four spans.

The line at bridge 5, Fig. 7, is in rock and on a side hill. At the center line of the pipe the surface of the ground is at nearly the same level as the bottom of the pipe, sloping at an angle of 50° to 80° at either side. A masonry retaining wall would have been 20 or more feet in height, with considerable rock excavation in the foundation. It was, therefore, decided to use a steel construction instead. The latter consists of a single girder 55.5 ft. long over all, with its ends resting on abutments, and of floor beams that carry the pipe; they have one end bolted to the girder, the other end being supported directly on the rock or on small, separate piers or low walls built on the rock.

On this bridge the line of the pipe follows a 7° vertical and a 14° horizontal curve. In order to conform to the curved horizontal alignment, it was necessary to vary the construction of each floor beam, as the center of the pipe support had to be placed at varying distances from the girder. The vertical curvature was maintained by varying the points of attachment of the floor beams to the girders, as described above.

Bridge 0 consists of two spans 34 ft. each, and is of the same type as bridge 5.

Bridge 1 is a steel trestle, 136 ft. 7 ins. long, consisting of three spans of 33 ft. 3½ ins. and two braced towers of 18 ft. 3½ ins. The end spans are supported on masonry abutments, while the tower posts rest on low piers.

Detailed plans showing all dimensions were made, and bids asked for per pound of finished bridge work, f. o. b., Chicago.

In calculating strains, the following loads were used:

Weight of water in pipe,	1 850 lbs.	per	lineal foot.
Weight of wooden pipe,	350 "	"	"
Total...........	2 200 "	"	"

The weight of the steel work was 250 to 300 lbs. per lineal foot. The unit strains used were 13 000 lbs. per square inch net in tension, and about 8 000 lbs. per square inch in compression.

Basic open-hearth steel was used, which, when tested in sample bars 2 ins. wide and 10 ins. between grips, met the following requirements:

Ultimate strength...54 000 to 62 000 lbs. per square inch.
Elastic limit ....31 000 lbs. per square inch.
Elongation in 8 ins..24 per cent.
Reduction of area...48 "
Also the usual bending and drifting tests.

All mill and shop work was inspected, the usual specifications for the best class of punched work being followed; but the holes for all field connections were drilled to fit turned bolts.

Erection of Bridges.—The bridges over Ogden River and bridge 0 were close to the highway and readily accessible. The other spans were located in the rocky part of the cañon, from 200 to 500 ft. above the bottom. The side slopes were too steep for building a wagon road, so that it became necessary to adopt some other means for handling the material. An inclined plane was therefore built opposite bridge 1. It consisted of a light timber trestle work which crossed the river and followed the sloping rock close to the ground at an average angle of fully 45°. Ties were placed about 3 ft. apart, and a light steel railroad track laid on them.

The cars containing the material were hoisted by means of a $\frac{5}{8}$-in. steel wire cable which passed around a sheave securely anchored at the top. Two horses working a sweep at the bottom were sufficient to raise a maximum load of 3 000 lbs. The empty cars were lowered by braking. The whole contrivance cost only a few hundred dollars, but served to hoist most of the bridge steel, besides a large amount of stave lumber and bands for the wooden pipe. The steel for bridge 6 was hoisted by the cableway elsewhere referred to.

After it was hoisted to the top the material was distributed by cars moved by mules along the light railway track which was built for the wood pipe construction. This was rather tedious work, owing mainly to the sharp curves in the line. The short girders 18 and 34 ft. long, came from the shop in one piece, but the longer, 55-ft. and 70-ft., girders were shipped in three pieces.

For erection, light, but well-braced, timber falsework was used, which, in some places, was 30 to 40 ft. high and rested on the rock below. Owing to its steep slope, it was not easy to find a good support for the bottom sills, and for one or two bents recourse was had to blasting. The total cost of erection, considering the light character of the work, was not excessive, being barely more than 1 cent per

pound. There was, however, no field riveting, as turned bolts were exclusively used.

The erection was done by the Pioneer Electric Power Company by day labor, as the steel bridges were not included in the pipe line contract.

Timber Trestle.—This trestle is also on the wooden pipe line, but close to its junction with the steel pipe. The material used was Douglas fir, with the sills resting on masonry piers.

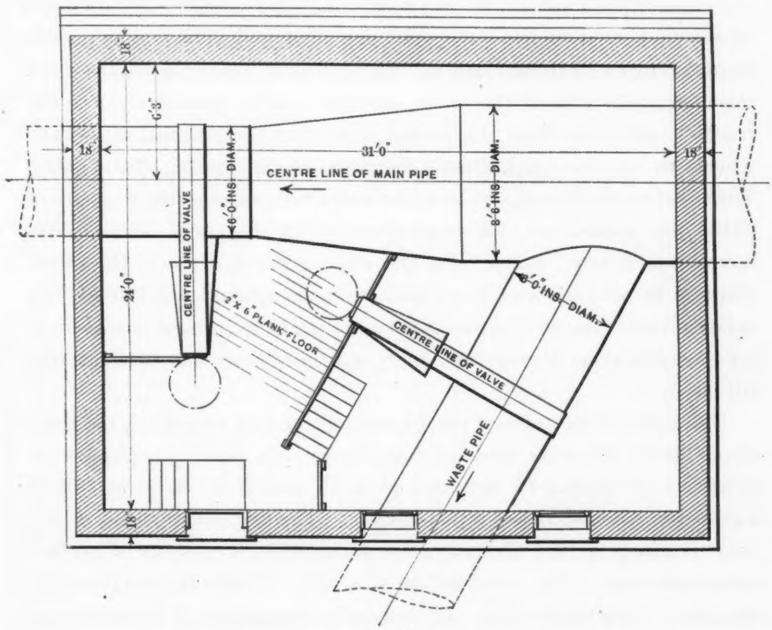

FIG. 8.

Masonry Abutments and Piers.—The abutments and piers for the bridges were built of rubble masonry laid in cement mortar. The stone was quarried close to the bridge sites, and consisted of unsquared stones. No attempt at regular courses was made, but the stones were selected and laid so as to break joints horizontally and vertically. English or German Portland cement was used for mortar in the proportion of one part of cement to three parts of sand. The exposed surface joints were pointed with cement mortar, and no projecting points or irregular edges were allowed.

Valves and Other Specials.—Between the inlet tower at the dam and the power house there are five large gate valves, besides the smaller blow-off and relief valves. Three of these valves are 72 ins. in diameter, and the other two 42 ins.

Two of the 72-in. valves are placed in the gate-house just below the dam, shown in Fig. 8. These two valves are identical in construction. They are horizontal valves, with double gates. There are two separate stems which are geared together and are operated by a hand-wheel. As the gates of these valves are very heavy, each gate has two bronze disks or wheels placed on the lower side, preceded and followed by a solid bronze scraper or track cleaner. These wheels run on a bronze track fastened to the case of the valve, and the scraper coming close to the tracks keeps them clear of mud and other obstructions, and allows the wheels to hug the track closely and prevent the binding of the gates. These valves were designed to withstand a maximum water pressure of 25 lbs. per square inch and weigh about 22 000 lbs. each. As the gate-house was nearly 7 miles from the end of the side track, they were shipped in sections and put together on the ground. Although the manufacturers feared that the valve seats might be injured in transit, it is believed that no damage was done, and the gearing was satisfactorily adjusted.

The third 72-in. valve is placed near elbow 2 of the steel pipe line, about 100 ft. below its junction with the wooden pipe. Its purpose is to permit the closing of the wood pipe, so that it can be kept full of water even when the steel pipe is empty. The hydrostatic head at this point is nearly 200 ft. The valve was designed for a pressure of 100 lbs. per square inch. The construction of a valve of this size and pressure was almost unprecedented. In general arrangement, it is similar to the lighter valves previously mentioned, but all parts are, of course, much heavier, and there is only a single valve stem. It has a 12-in. bypass, and is operated by a hydraulic lift supplied with pressure water from the main pipe above the valve.

It is 8 ft. high, and 4 ft. from face to face of flanges, and its extreme length, including the flanges, is 24 ft. 6 ins. The hydraulic lift cylinder is lined with bronze to prevent corrosion, the spindle within it being steel with a bronze casing 4½ ins. in diameter. The valve stem proper is made of the best bronze. This valve is fitted with the bronze scraper wheels and track already described.

The site of this valve was only three-quarters of a mile from the railroad siding, but fully 300 ft. above it, and accessible only by such temporary roadways as had been constructed for building the pipe line. The total weight of this valve is 52 000 lbs. It was, of course, shipped in sections, but it was found impossible to reduce the weight of the heaviest single piece below 20 000 lbs. Transporting such large masses was, of course, slow and difficult, and twenty-four horses were required to move the heaviest piece. The valve was, however, safely transported and put together without accident. It is believed to be the heaviest valve yet built.

The foundations for these valves were concrete blocks, carried down

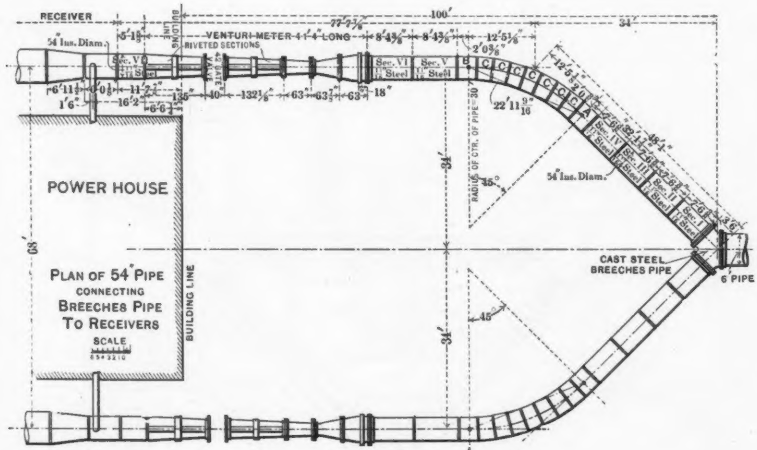

FIG. 9.

3 to 5 ft. to a solid gravel bottom. They were made wide enough to support the ends of adjacent pipe sections, so as to relieve the cast-iron end flanges of the valves of strain. The permissible pressure on the soil was taken at 1 000 lbs. per square foot.

Besides these large valves, there are two smaller ones 42 ins. in diameter, which are placed between the lower end of the 6-ft. pipe and the power house on the two branches that lead to the receivers. These branch pipes are 54 ins. in diameter, their general construction being the same as that of the larger pipes. They are reduced to 42 ins. by the introduction of the Venturi meters, thus permitting the use of the smaller valves. These valves were tested to 400 lbs. pressure

per square inch. Their general arrangement is the same as that of the larger valves. They have two separate stems and are moved by hand gearing.

The connection between all the valves and the steel conduit is made by weldless, rolled steel angle flanges. One leg is riveted to the pipe by a double row of $1\frac{1}{8}$-in. rivets, and the other is bolted to the

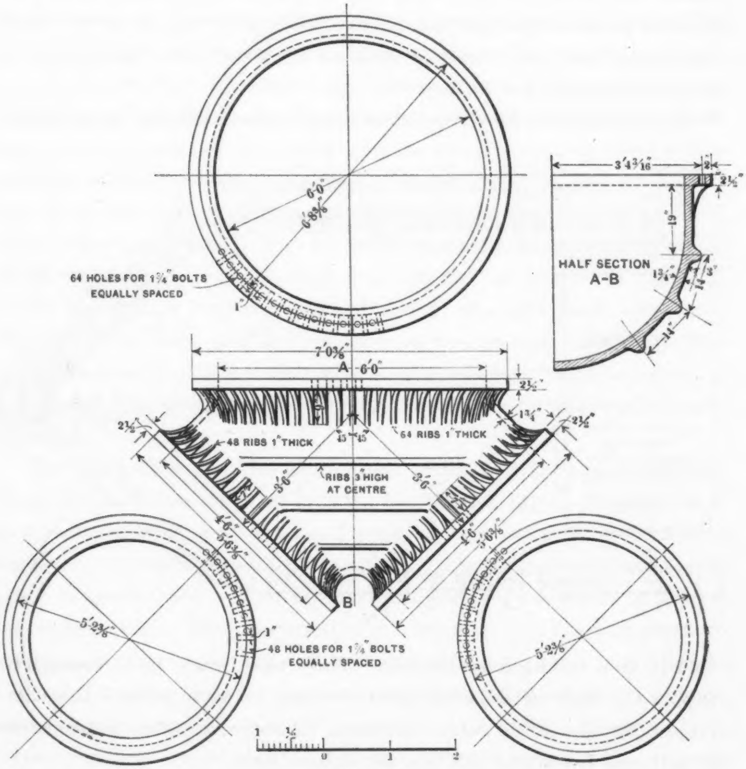

FIG. 10.

flange of the valve. Corrugated copper gaskets and red lead are used to make this connection water tight. The location of these valves and of the Venturi meters is shown in Fig. 9.

Venturi Meters.—The flow of water is to be measured continuously by two Venturi meters, one in each of the branch pipes supplying the receivers. They are built of cast iron for a pressure of 250 lbs.

per square inch, the sections being connected by flanges and bolts. The registers are of the latest type made, in which weights are used for operating the mechanism. They are placed inside of the power house and are connected with the meters by ¾-in. seamless brass tubing. The registers will record the flow from a minimum of 15 cu. ft. per second to a maximum of 130 cu. ft. If the flow exceeds 130 cu. ft., it will pass the meter without injuring it, but the excess will not be recorded.

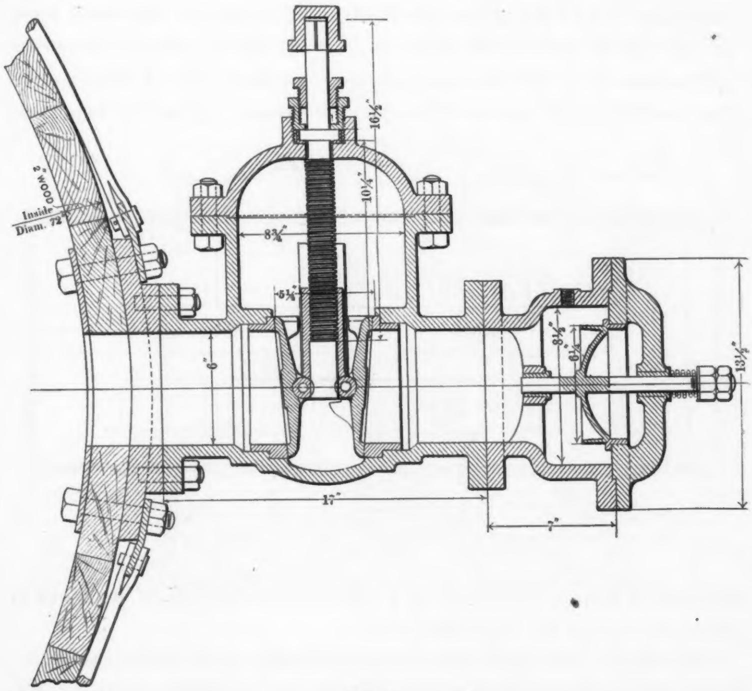

FIG. 11.

Breeches Pipe.—The connection between the 72-in. steel pipe and the two 54-in. branches is made by a steel casting, the general appearance of which is shown in Fig. 10. The pressure at this point is nearly 200 lbs. per square inch. Connection with the steel pipes is made by cast-steel angle flanges and bolts. A heavy concrete block is built around the casting, to secure it against the heavy longitudinal pressure, and to relieve the flanges and the adjacent pipe sections from strain.

Outlet Shaft and Stand Pipe.—At Station 247, the pipe line is in tunnel and but little below the lower hydraulic grade line, and about 50 ft. below the surface of the ground. This point was selected for the location of an outlet shaft. It is 6 ft. in diameter, and was sunk from the top through the solid rock to connect with the tunnel. With a full reservoir the top of the shaft comes close to the upper hydraulic grade, if the virtual slope is assumed equal to 0.002. The pressure in the pipe below the shaft can never exceed that due to the head of water corresponding to the top of the shaft. This reduces the static head, on the lower part of the pipe line, about 50 ft. In case the lower valves near the power house are closed, this shaft will, of course, overflow until the inlet valves at the dam are closed. A further important

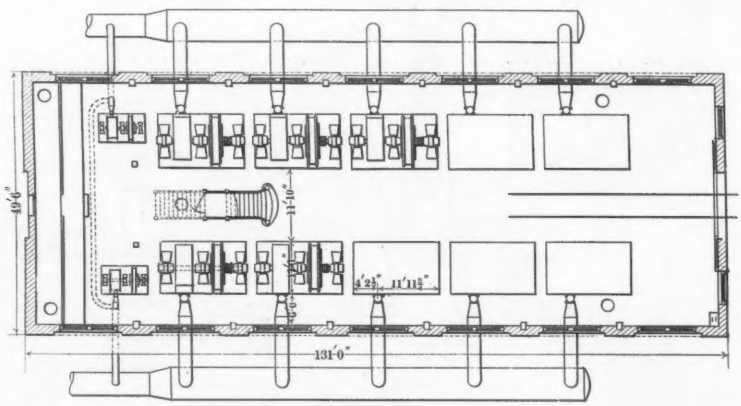

FIG. 12.

function of the shaft is to act as a relief outlet in case of accident to the lower part of the pipe line.

This shaft is not lined, but connects directly with the tunnel below. The wooden pipe in this tunnel is left out for a distance of about 100 ft., the pipes being connected to the tunnel by steel angle rings and flanges similar to those used for joining the steel and wooden pipes, and are bedded in concrete.

In addition to this shaft, a stand-pipe was built which connects with the 6-ft. steel conduit just below its junction with the wooden pipe, and a short distance above the heavy 72-in. valve. This stand-pipe is a wooden stave pipe, 49 ins. in internal diameter, built of twenty-four staves and banded in the same way as the 6-ft. pipe. It is laid on

a tangent and follows the contour of the ground up to the hydrostatic grade line. It is 550 ft. long, and is intended mainly to act as a safety valve in case the large valves below should be too suddenly closed, or in case of a collapse of the pipe.

These two relief openings will always permit the water to rise freely to the levels corresponding to the pressure at the points where they leave the main conduit. As the pipe is of practically constant diameter and of the same construction from the dam to the lower stand pipe, there will be an excellent chance for determining the true coefficient of friction in the wooden pipe for different velocities of flow.

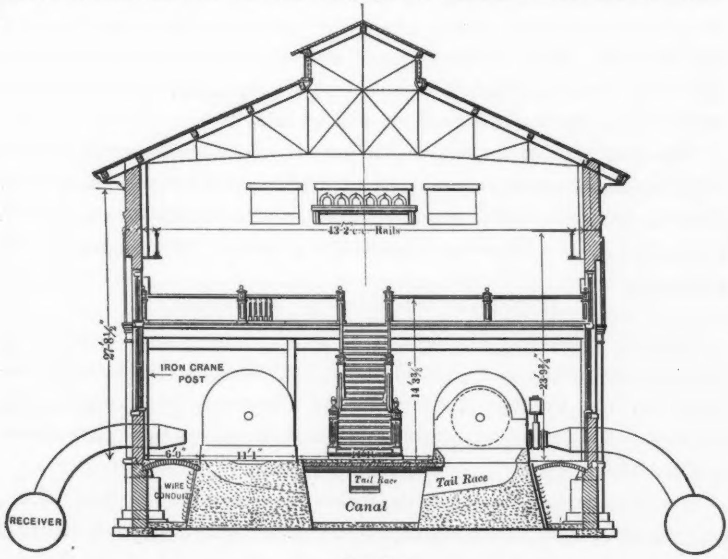

FIG. 13.

Air Valves.—These are of two kinds: single valves, 6 ins. in diameter, Fig. 11, and "group valves," consisting of ten 2-in. valves in each group, which are closed by rubber balls, giving an aggregate area equal to a single 6-in. opening; besides this, they have a $1\frac{1}{2}$-in. blow-off valve.

During the process of filling the pipe with water all these valves remain open, allowing the air to escape, until the water pressure closes the valves one after the other. When the pipe is to be emptied, the reverse process takes place, the valves opening as the water flows out, thus permitting the air to enter as fast as the water escapes. A 6-in. gate valve was placed between the air valves and the main pipe. This

gate is intended to be left open under normal conditions, being closed only in case of damage to the air valve. These air valves are placed at all summits on the wooden and steel pipes.

Blow-Off or Mud Valves.—These are placed at all depressions in the pipe, both for emptying the pipe and also for removing accumulations of sand, earth and other foreign matters. They consist of 6-in. angle gate valves, through which the water is discharged into small timber flumes laid in covered trenches, and leading to the river.

To guard against injury from the sudden closing of valves, etc., a number of relief or safety valves are used close to the power house, which allow water to escape when the pressure exceeds 200 lbs. per square inch. Five of these valves are placed on the 6-ft. pipe just above the breeches pipe, five on each of the receivers, and one on each intake pipe between the receivers and wheels.

The large valves are enclosed in gate-houses of masonry and frame construction, large enough to protect them from the weather and allow of their operation. The smaller valves and the manholes are covered by timber boxes to protect them from frost and accidental disturbance.

Hydraulic and Electric Machinery.

For the following description of the hydraulic and electric machinery, the author is indebted to Mr. L. S. Boggs, the electrical engineer of the Pioneer Electric Power Company, in charge of its erection. A plan and transverse section of the power house are shown in Figs. 12 and 13.

The installation comprises the following apparatus: Five 750-K. W. polyphase 2 300-volt generators; two 100-K. W. direct-current 500-volt exciters; five 1 200-H.-P. Knight water-wheels; two 135-H.-P. Knight water-wheels; one 7-panel generator switchboard; one 12-panel distributing switchboard; nine 250-K. W. step-up transformers; two blowers or cooling outfits; one 15-ton traveling crane; two Venturi water meters.

Receivers.—As noted in the general description of the works, the water is delivered from the pipe conduit into two receivers, which are buried in the ground, one at either side of the power house. They are 6 ft. in diameter, and, in their general appearance and the material used, closely resemble the regular steel pipe conduit. It may be noted, however, that the thickness of the metal is increased to $\frac{7}{8}$ in. in

order to allow for water-hammer. Besides this, the edges of all plates and straps were planed, and the rivet-holes reamed out fully $\frac{1}{8}$ in. after punching.

The receivers are provided with five safety valves each, which discharge when the pressure exceeds 200 lbs. per square inch, and an outlet gate at the bottom. From each of these receivers, five 30-in. and one 10-in. intake pipes extend to the walls of the power house to connect with the water-wheel nozzle pipes. Between these intakes and the nozzle pipes are placed the following valves, in order named: One 18-in. geared gate valve, one 18-in. hydraulic gate valve, and one 18-in. butterfly valve.

The 18-in. geared gate valve is only to be used in case of repairs to the particular machine that it governs, and is left open on all other occasions. The 18-in. hydraulic gate valve is piped up to a small D valve, which is placed back of the switchboard and under the floor, and by means of a lever on the switchboard, connected to this D valve, the gate can be opened or closed at the operator's will. This valve is the one which is to be used for starting or stopping a wheel. The 18-in. butterfly valve is operated by means of a worm gear from the governor, and is used in checking the speed of the wheel by reducing the head or pressure near the nozzle, and thus avoiding a sudden fall of head in the main pipe line, which would be detrimental to the proper working of the plant.

The nozzle for the water-wheels has six rectangular openings or ports $1\frac{1}{16}$ x $3\frac{1}{2}$ ins. in area. This nozzle is bolted to a tapering cast-iron pipe, securely fastened to the base of the machine, and the ports in the nozzle are made continuous, with a separation between each of them $\frac{1}{2}$ in. thick. Sliding back of the ports in this nozzle is a tongue, connected to the piston rods of two hydraulic cylinders which are placed one on each side of the head of the nozzle. These hydraulic cylinders are piped to another D valve, under the floor, back of the switchboard, which is also controlled by a lever on the switchboard. The operator is thus enabled to close one or more of the nozzle ports as he may desire. On the opposite side of the water-wheel from these hydraulic cylinders is a hand-wheel, which is geared to a rack that moves a similar tongue for opening or closing the nozzle ports on its extreme end. The levers that operate the hydraulic gate and nozzle are placed near the top of the switchboard. The set of levers for each water-wheel

is placed in the panel governing the generator which is driven by the wheel in question, so that the operations required in starting or stopping these machines are reduced to a minimum.

There is also between these levers an indicator with two hands, one showing the movement of the hydraulic gate and the other that of the nozzle.

Water-Wheels.—The water-wheels are 58 ins. in diameter, and have 45 bronze buckets cast in one solid piece; 14 of these will, when the nozzle ports are all open, receive the water at the same instant. The centers of the wheels are made of cast steel, the buckets being pressed on these steel centers, and secured with turned bolts, fitted in reamed holes, passing through both pieces of metal. These wheels were bored to fit, and are keyed to the generator shaft, each wheel being faced and perfectly balanced.

Each water-wheel is provided with two fly-wheels, about 70 ins. in diameter, each of which weighs about 2 tons, and is placed inside of a housing on each side of the wheel. These fly-wheels are banded with $\frac{3}{4}$ x 5-in. Ulster iron, shrunk on hot. They are split in three parts and are filled with metal, banded, bored to fit, and keyed to the generator shaft. They are turned on the face and nicely balanced.

The armature, armature shaft, two fly-wheels and one water-wheel, which comprise the moving parts, weigh as much as 15 tons, which greatly helps in maintaining a uniform speed, notwithstanding changes of head in the main pipe, or changes in the generator load.

The water-wheel, fly-wheels, nozzle and the two hydraulic cylinders are encased in a steel housing, bolted to the machine bed-frame. On the top of this housing is placed the speed-regulating apparatus or governor, which is driven from the water-wheel end of the armature shaft and is geared to the shaft of the worm gear which operates the butterfly valve already referred to. There is also a hand lever on the shaft of this butterfly valve that is used in regulating the opening until the governor picks up, as in the starting of a machine.

Between the two lines of machines and down through the center of the building underneath the concrete floor is the spillway into which the wheels discharge the water, and through which the water is carried back to the river from which it was taken.

On each side of the plant, near the generator switchboard and facing each other, are the registers for the two Venturi water meters elsewhere described.

Generators.—The generators used in this plant are of the General Electric type, with 24 poles, and, at 300 revolutions per minute, have an output of 750 K.-W. at 2 300 volts, and a frequency of 60 cycles per second, and the factory tests show that the variation in volts will be less than 5% with a constant speed, should the full non-inductive load be thrown off or on.

The bed plates of the generators were filled with cement after they were leveled up and securely anchored to their respective foundations. Between the machine foundations and the building foundation wall, on each side of the building, is a subway which runs the entire length of the building and across the rear, and in this subway are carried all the necessary piping for water-wheel controllers and all the wires between the generators and the switchboards. The cable connecting each generator to its respective panel on the generator switchboard is a three-wire concentric 250 000 C. M. lead-covered cable, and the exciting wires are a two-wire concentric No. 4 B. & S. lead-covered cable. In fact, all the machine connections to the switchboard are lead-covered cables.

Exciters.—The exciters used in this plant are six-pole 500-volt machines, and will give 100 K.-W. at 550 revolutions per minute. Each of these machines is ample for the entire exciting current that will be needed for the ten 750-K.-W. alternators, and they are each direct connected to a 135-H.-P. Knight water-wheel similar in every way to the 1 200-H.-P. water-wheels previously described. These exciter water-wheels are cross-connected to each receiver, so that either exciter can be operated from either receiver. The advantage of this is self explanatory.

Switchboards.—The generator switchboard consists of seven marble panels; five of these are for the alternators, one for the exciter, and one the instrument panel.

Each generator panel has the following apparatus on it: One 150-volt Thomson alternating voltmeter; one 1 000 K.-W. Thomson alternating wattmeter; one 25-ampere Weston ammeter; three S. P. Quick Break, D. T., 2 300-volt, 200-ampere switches; three S. P., 2 300-volt, 200-ampere fuse boards; two S. P., Q. B., D. T., 600-volt, 30-ampere switches; one field rheostat; two pilot lamps; one station transformer; three current transformers; two sets three-phase bus-bars.

The exciter panel is equipped with the following apparatus: Two

600-volt Weston voltmeters ; two 300 ampere Weston ammeters ; two pilot lamps ; two S. P., Q. B., D. T., 600-volt, 200-ampere switches ; four S. P., 600-volt, 200-ampere magnetic cut-outs ; two field switches ; two Carpenter enamel field rheostats.

The instrument panel has the following apparatus: Two pilot lamps; two 5 000-K.-W. Thomson alternating wattmeters; two 130-volt Bristol recording volt meters ; one Bristol recording water-pressure gauge; one synchronizer with two plug boards; one ground detector with two plug boards ; two station transformers ; eight current transformers.

These panels are 36 x 90 x 2 ins. each. They are built of blue Vermont marble, with nickel fittings. There are two sets of three-phase bus-bars on the back, extending the entire length of the seven panels, as well as two bus-bars, also running their entire length, from which the exciting current is taken.

The speed-indicating apparatus consists of a tachometer coupled to the shaft of a small synchronous motor; there are two of these.

From the generator switchboard the current is carried to the distributing board by means of copper bars, of which there are two sets of three, connecting the two sets of bus-bars on the generator board with the two sets of bus-bars on the primary panels of the distributing board.

The distributing switchboard is in a gallery in the rear of the building and over the generator switchboard. Back of this distributing switchboard are the nine 250-K.-W. step-up transformers, the lightning arresters, and the two blowers for cooling the transformers.

The distributing board is divided into two sections, one the primary section, and the other the secondary section. Each section has six panels. In the primary section, four of the panels are for the low side of the step-up transformers, the remaining two being for the local distributing lines in the vicinity of the power plant. In the secondary section, four of the panels are for the high side of the step-up transformers, and two for the long-distance transmission lines.

The 2 300-volt primary panels are each equipped with the following apparatus: Three 350-ampere Thomson alternating ammeters; one Thomson recording wattmeter; three S. P., Q. B., D. T., 2 300-volt, 200-ampere switches; three S. P., 2 300-volt, 200-ampere fuse boards; three station transformers; two current transformers; two sets three-phase bus-bars.

The 16 100-volt secondary panels have on them three S. P., Q. B., D. T. switches; three plug tube cutouts and two sets of three-phase bus-bars. The length of this distributing switchboard is 39 ft., and it is built of blue Vermont marble.

Back of the distributing switchboard and on a raised platform are placed the step-up transformers. These transformers raise the potential of the current from 2 300 to 16 100 volts, at which pressure it goes into the long-distance transmission lines. The transformers are connected up in sets of three, and the delta connection is used on both sides. At each end of the building in the gallery are placed the two blowers, direct connected to a $2\frac{1}{2}$-H. P. 500-volt direct-current motor. These blowers are used in cooling the step-up transformers, and force the air up through the bottom of the transformers, around the coils, and out at the top, thus giving good ventilation.

Transmission Line.—The transmission line is calculated to deliver about 3 000 H.-P. at the sub-station in Salt Lake City, distant about 38 miles, and consists of two circuits, making six wires of No. 1, B. & S. gauge.

The poles used on this line are of Oregon cedar, and are good, clear, straight poles, 30, 40, 50 and 70 ft. long, with 9-in. and 10-in. tops. There are two cross-arms on each pole for the wire; two wires are on the top arm 4 ft. apart, and four wires on the bottom arm each 2 ft. apart, a circuit being on each side of the pole; and these wires are so arranged that should a plane be placed perpendicular across the circuit it would show an equilateral triangle, with a wire at each angle, the length of the sides being 2 ft. These wires are transposed about every half mile. By this arrangement of the pole line wire, the inductive effect is reduced to a minimum.

About 6 ft. below the second cross-arm on the pole is a two-pin cross-arm, on which the telephone wires are strung, being transposed about every four poles, there being an average of about 50 poles per mile.

The current is fed into the transmission line at the power plant at 16 100 volts, and delivered to the step-down transformers at 13 800 volts. This will give an energy loss of about 10% in the line, and a potential loss of about 14 per cent. The substation step-down transformers deliver this current to the local distributing lines again at 2 300 volts. There are at present nine 250-K.-W. step-down transformers at

the substation, connected in a way similar to the step-up transformers, and the switchboard in the substation is similar in every respect to the distributing board in the power plant gallery. The cooling apparatus here is also identical with that used in the power plant, except that the motors used here are 60-cycle induction motors.

While the transmission lines are at present capable of delivering 3 000 H.-P. at the substation, with a 10% energy loss, if it should become necessary, the step-up transformers can deliver more than this by changing three wires on their high side, and delivering the current into the transmission lines at 27 000 volts. Thus the line capacity would be more than doubled.

The present installation of the power plant is only capable of delivering 3 750 K.-W. to its lines, but ample provision has been made to increase this amount to 7 500 K.-W. by installing five more 750 K.-W. machines, as new industries or manufactures spring up as the result of the advantages offered to them in Ogden and Salt Lake City.

There is one important feature in the arrangement of the machinery which should be noticed, viz., the complete duplication of all parts. All portions of the plant below the breeches pipe casting, at the lower end of the 6-ft. conduit, are absolutely symmetrical about the center line of the power house, each side being entirely independent of the other. This applies not only to the pipe and the receivers, but to all parts of the switchboards, etc., as well as to generators and water-wheels. Either one of the exciters, also, is capable of providing sufficient current for all the large generators, and can be run with water from either receiver. The advantage of this arrangement is that an accident to either receiver, or to one or more wheels or generators, would not result in the shutting down of the entire plant, but at the worst of only one side. For a short period all the required power could probably be supplied from one side of the power house.

Machine Shop.—The machine shop is a one-story brick building, covered with a standing seam steel roofing. The central part of the building is occupied by a well-equipped machine shop, while two wings serve respectively as a store-room and a superintendent's office.

The Dam.

The general location of the dam was determined by the topography of the upper valley, but it required considerable study to fix its exact

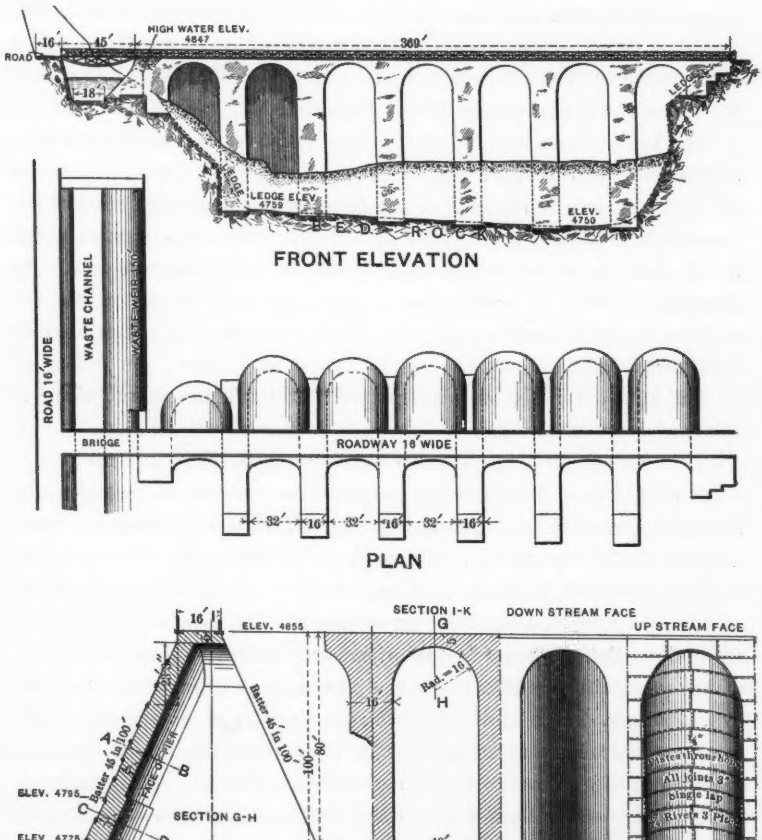
HIGH WATER ELEV. 4847
ROAD
16′
45′
369′
18
LEDGE
LEDGE ELEV. 4759
ELEV. 4750
BED ROCK
FRONT ELEVATION
ROAD 16′ WIDE
WASTE CHANNEL
BRIDGE
ROADWAY 16′ WIDE
32′
16′
PLAN
ELEV. 4855
SECTION I-K
DOWN STREAM FACE
UP STREAM FACE
Batter 45 in 100
FACE OF PIER
SECTION G-H
ELEV. 4795
ELEV 4775
BED ROCK
95.84
Rad.=10
48′
32′
Plates
Steel Pl.
Anchor Bolt
ROADWAY
SECTION E-F
SECTION C-D
SECTION A-B

Fig. 14.

site. A number of borings were made to the bed-rock, and the latter was explored with a diamond drill to a depth of from 3 to 15 ft. The location chosen combines the advantages of a short dam with a comparatively high position of the bed-rock. The cross-section is shown on the general plans of the dam, Fig. 14.

The bed-rock underlying the bottom is of fairly compact limestone, covered by 35 to 45 ft. of loose water-bearing gravel. On the sides of the cañon there are outcrops of the same formation. The crest of the dam is about 400 ft. long and its elevation above the ground about 60 ft., making a total height of fully 100 ft. above the bed-rock. An inexpensive form of waste water-way is provided by excavating the solid rock of the north bank, so that the dam itself is not used as an overflow weir.

The inlet tower for supplying the conduit will be placed close to the south end of the dam.

Although the location is entirely favorable to the construction of a masonry dam of the usual form, and the cost would not be excessive, it was determined to inquire into the feasibility of adopting some different design by which a saving might be expected. The idea was entirely excluded, however, of doing so at the expense of either safety or durability, by making a lower assumption as to the forces to be resisted, or the necessary factors of safety. It was believed, however, that it would be possible to reduce the amount of masonry required by adopting a design in which the stresses coming on every part would be more uniform and definite than in massive dams, so that the strength of the material would be more fully utilized. Following out this line of investigation, a number of different designs were studied in detail.

The plan finally adopted provides for a concrete dam consisting of isolated piers united by segmental arches. Both in the quantity of material used and the cost of construction it promises to be considerably cheaper than a dam of the usual type. It is believed, too, to meet all necessary requirements as to strength, water-tightness and durability. The statement as to the saving in cost is based on the result of an actual bidding made by a number of experienced contractors on detailed plans and specifications. While the bids differed largely as to the actual amounts, they were, in every case, considerably lower than the tenders for a masonry dam which were made at the same time.

In addition to this design, the question was studied of substituting a steel structure for the upper 60 ft. of dam. Although, under the conditions prevailing in Ogden Cañon, a steel dam proved to be uneconomical, there may be places where the result would be different. For this reason some forms of steel dams, given in Appendix B, may be of some interest.

Concrete Dam.—The dam consists of concrete masonry, but a thin steel plate covering is bolted to the up-stream face to prevent abrasion and the percolation of water. As shown in Fig. 14 there are to be six separate piers and two abutments, which are joined together, both on the up-stream face, and on top of the piers, by circular concrete arches. The piers are 16 ft. thick, while the arches have a clear span of 32 ft. The extrados of the arches is cylindrical, with a radius of 25 ft. The thickness of the arch rings varies, being 6 ft. for the upper 60 ft. of dam, 7 ft. for the next 25 ft., and 8 ft. below this point.

The arches at the top, which will carry a roadway 16 ft. wide, are semi-circular, the intrados having a radius of 16 ft. They are practically continuous with the arches of the up-stream face. The spandrel spaces above these arches will also be filled with concrete, and a stone coping will be laid on top, on either side. On top of this coping there will be an iron hand-railing or an ornamental stone parapet.

The steel facing will be ¼ in. thick. The plates in front of the arches will be 22 ft. long, while the flat plates on the piers will be 10½ ft. in length, making lap-joints with the curved plates on the arches. There will be lap-splices, with a single row of ¾-in. rivets, spaced 3 ins. apart. The joints will be made water-tight by calking. The surfaces coming in contact with the concrete will be cleaned, but not painted, while the outer surfaces will be painted with an asphaltum paint.

Stresses and Cross-Sections.—The dam is designed purely as a gravity structure, and the way in which the forces act will be readily seen by an examination of the plans. The arch-rings act simply to transfer the water-pressure to the adjacent piers, which must be of sufficient size and strength to withstand the entire hydrostatic pressure that comes on both piers and arches. As customary, the water is assumed to extend from the top of the dam to bed rock, but is not supposed to penetrate beneath the piers and exert an upward pressure.

The arches are circular segments, so that their central lines coin-

cide exactly with the line of pressure for water pressures acting normally to the extrados. Hence the compressive strains are uniform in the arch-ring at any given elevation and are readily found by the formula $T = pR$, in which T is the compressive strain in an arch-ring 1 ft. in height, p is the water-pressure in pounds per square foot, and R is the radius of the center line in feet. The actual stresses, as thus computed, are quite moderate, being 96 lbs. per square inch for the 6-ft. arch, 106 lbs. per square inch for the 7-ft. arch, and 120 lbs. per square inch for the 8-ft. arch. The minimum thickness of 6 ft. is arbitrarily fixed from practical considerations.

The determination of the best and most economical cross-section for the piers is a somewhat tedious, tentative process. The requirements as to strength and stability are the same as for a continuous masonry dam, but the water pressure to be withstood by each foot of pier is much greater, so that a heavier section is needed. Each pier acts as an abutment for two arches, but, owing to the symmetry of the construction, the components of the thrust parallel to the face will always balance. Hence, the resulting force tending to overturn the pier acts at right angles to its face, and is equivalent to a pressure on a plane, the width of which is equal to that of the pier and of two half arches. As the piers are 16 ft. wide and the arch-span is 32 ft., the pressure of the water on the pier is equal to that which would be exerted by a fluid with a specific gravity of 3, *i. e.*, weighing 3 x 62.5 or 187.5 lbs. per cubic foot. The weight of the masonry is taken at 145 lbs. per cubic foot.

The usual standards for strength and stability were followed, and the graphic analysis of the adopted cross-section is shown in Fig. 15. All forces are given in cubic feet of masonry.

As there shown, the factors of safety are the following:

As to Overturning.—The moment of the forces which resist overturning, when taken about the down-stream edge of the dam, at any elevation, are more than twice as great as the moment of overturning at the same point.

As to Sliding.—The angle between the resultant on any joint and the normal to the joint nowhere exceeds $\tan.^{-1} 0.85$ or $40^\circ 22'$. Hence, a coefficient of friction of 0.85 in the masonry will be sufficient to prevent sliding. This is considered amply safe in the case of a concrete dam in which there will be no joints, properly speaking, but, on the contrary,

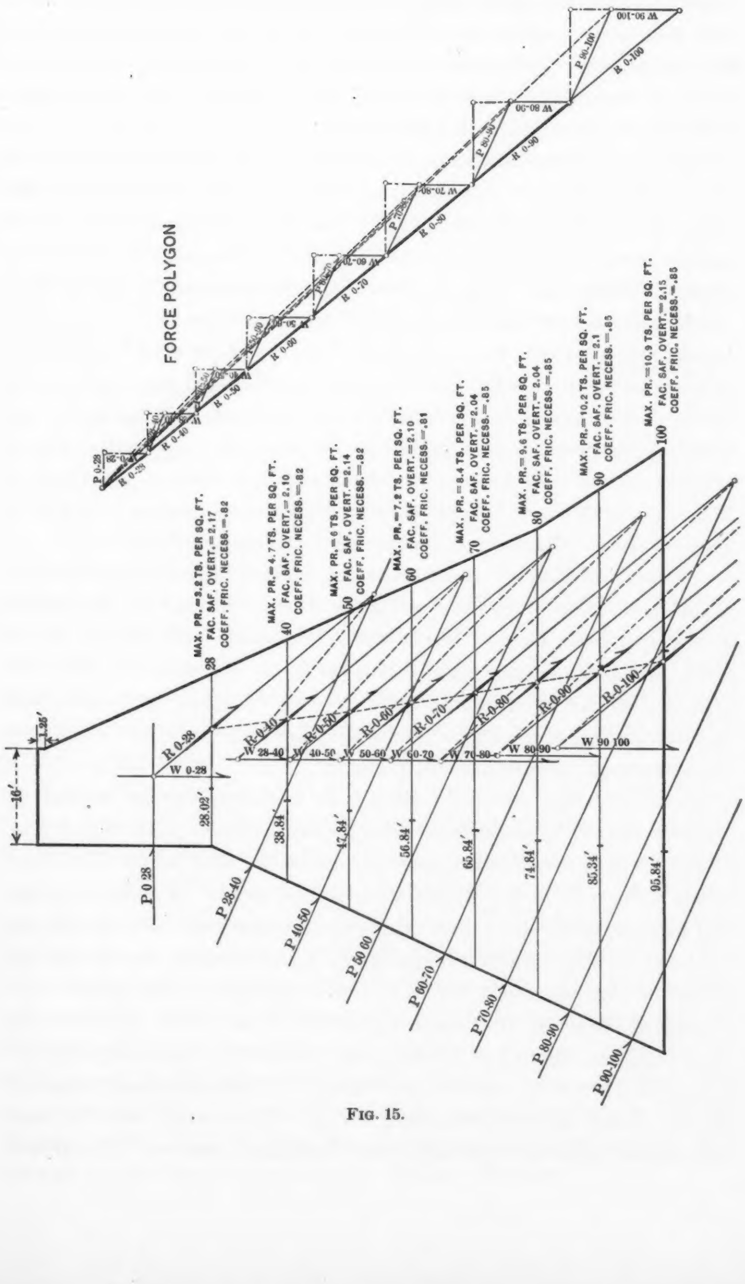
FORCE POLYGON
MAX. PR.=3.2 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.17
COEFF. FRIC. NECESS.=.82
MAX. PR.=4.7 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.10
COEFF. FRIC. NECESS.=.82
MAX. PR.=6 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.14
COEFF. FRIC. NECESS.=.82
MAX. PR.=7.2 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.10
COEFF. FRIC. NECESS.=.81
MAX. PR.=8.4 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.04
COEFF. FRIC. NECESS.=.85
MAX. PR.=9.6 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.04
COEFF. FRIC. NECESS.=.85
MAX. PR.=10.2 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.1
COEFF. FRIC. NECESS.=.85
MAX. PR.=10.9 TS. PER SQ. FT.
FAC. SAF. OVERT.=2.15
COEFF. FRIC. NECESS.=.85
28
40
50
60
70
80
90
100
16′
1.25′
28.02′
38.84′
47.84′
56.84′
65.84′
74.84′
85.34′
95.84′
R 0-28
R-0-40
R-0-50
R-0-60
R-0-70
R-0-80
R-0-90
R-0-100
W 0-28
W 28-40
W 40-50
W 50-60
W 60-70
W 70-80
W 80-90
W 90-100
P 0 28
P 28-40
P 40-50
P 50 60
P 60-70
P 70-80
P 80-90
P 90-100

FIG. 15.

considerable cohesive strength. It is true that in standard sections for masonry dams the angle between the resultant and the normal is usually somewhat smaller than the above value. In such dams, however, the dimensions of the cross-section are not increased by this requirement, as the length of the joints are mainly fixed by the necessity of keeping the resultant within the middle third.

As to Internal Stresses in the Masonry.—The resultant at all joints is kept within the middle third, so that there are no tensile stresses. The compressive strains for a full reservoir nowhere exceed 10.7 tons per square foot, this being the stress at the bottom, and are less at other points. While this value is somewhat greater than is usual in dams 100 ft. high, it leaves a large factor of safety, and has been exceeded in actual constructions, some of which have stood for several centuries. It must be borne in mind here, too, that in standard dam sections the lengths of joints up to a height of 100 ft. are not determined by the limiting compressive strains, but by the necessity of avoiding tensile stresses and of maintaining a proper stability against overturning. Where the water face is vertical, both of these requirements are met by keeping the resultant at all joints within the middle third.

The section adopted under these conditions is approximately trapezoidal, and differs from the standard section by having a heavy batter on the up-stream face. This batter is essential. The length of the joints in the upper part of the dam (as far as elevation 80) were determined by the requirement as to the middle third, but below that elevation it was necessary to extend the base so as to keep the stresses on the masonry within moderate limits.

Specifications for Material.—Both piers and arches are to be built of concrete, mixed by machinery and carefully rammed into well-braced molds, so as to form a homogeneous, monolithic structure. The steel-facing will serve as the upper side of the molds. Portland cement will be exclusively used, the proportions being one part of cement, two of sand, and four of broken stone, for the arches, for the exterior 2 feet of the piers and for all concrete deposited under water. For the rest of the work, the proportions will be one, three and five. In computing the amount of cement used, it shall be measured as packed in barrels, the cubic contents of a barrel of Portland cement weighing 400 lbs., being taken as equal to $\frac{1}{8}$ cu. yd. The cement will be carefully tested before acceptance as to strength and fineness. The broken

stone shall be clean, durable limestone, while the sand must be clean, coarse and silicious. The steel used for plates and rivets shall conform to the specifications given in Appendix A.

Method of Construction.—The method of sinking foundations will depend on the nature of the material and the amount of water encountered in the pits. It is expected that the excavation of separate trenches for the piers will greatly reduce the difficulty of handling the groundwater. The earth excavation will be carried down with sloping sides until water is reached. Below this level the trenches will be timbered and braced. The piers and arches will be sunk into the bed-rock 2 or 3 ft.

Quantities.—The amount of material for the above arch dam, as well as for a dam of the ordinary form, is given below:

	Ordinary dam.	Arched dam.
Concrete Masonry.—		
In dam proper	37 200 cu. yds.	26 000 cu. yds.
In overflow weir	1 700 " "	1 700 " "
Total concrete	38 900 cu. yds.	27 700 cu. yds.
Excavation.—		
Earth excavation	33 700 cu. yds.	27 550 cu. yds.
Rock excavation	2 400 " "	2 400 " "
Steel-plate facing		350 000 lbs.

The unit prices bid by the several contractors for the different classes of work were almost identical for both forms of dam, so that the total cost of the new form was from 12% to 15% less than that of the old type. By omitting the steel plate facing and substituting an asphalt coating, which appears to the author quite feasible, a still greater saving would be effected.

The work was carried out under the direction of C. K. Bannister, M. Am. Soc. C. E., as chief engineer, while Messrs. Willard Young and H. M. McCartney successively held the position of assistant chief engineer. Mr. R. F. Hayward was consulting engineer for the hydraulic and electric equipment, while George H. Pegram, M. Am. Soc. C. E., acted in an advisory capacity as consulting engineer. The location and early construction were in charge of Mr. F. N. Snyder, who was succeeded by Mr. S. E. Reaugh. To the author were entrusted the designing of the pipe conduit and its details, and the studies for the dam, as well as the mathematical and technical work connected with the plant, excepting the electrical and hydraulic machinery and transmissions. Mr. G. E. Rhodes was in charge of the work on the pipe conduit for the contractors, Messrs. Rhodes Brothers.

APPENDIX A.

EXTRACTS FROM STEEL PIPE SPECIFICATIONS.

"*Requirements for Steel Plates.*—The steel shall be of the class termed 'soft medium,' and shall be made by the open-hearth process, either the basic process or the acid process, as the engineer may determine. If made by the basic process, the percentage of phosphorus shall not exceed 0.04 and of sulphur shall not be greater than 0.04; if made by the acid process, it shall not contain more than 0.07% of phosphorus and not more than 0.04 of sulphur. The percentage of manganese shall not be greater than 0.60 per cent. Each sheet shall be uniformly homogeneous in quality, and should a reasonable doubt exist as to the quality or uniformity of the steel furnished, the engineer may order additional tests before acceptance.

"Test pieces shall be furnished from at least 20% of the finished material of each melt, but at least two test pieces shall be made from every melt. The plates or sheets from which test pieces are taken shall be selected at random by the inspector, and each piece shall be numbered with the corresponding melt number.

"Tensile test pieces shall be at least 16 ins. long, and shall have for a length of 8 ins. a uniform planed-edge sectional area of at least $\frac{1}{2}$ sq. in., the width in no case to be less than the thickness of the piece.

"Bending test pieces to be 12 ins. long, and to have a width not less than four times the thickness, with edges planed smooth.

"Punching test pieces shall be $1\frac{3}{4}$ ins. wide and not less than 10 ins. long.

"Drifting test pieces shall be 3 ins. wide and not less than 5 ins. long.

"Test pieces as above shall give results as follows:

"Ultimate strength, 55 000 lbs. to 65 000 lbs.

"Elastic limit, not less than one-half ultimate strength.

"Elongation, not less than 24% in 8 ins.

"Reduction of area at fracture, at least 48 per cent."

"All fractures shall be fine, silky and free from crystalline appearance, or from indications of injurious treatment or insufficient working.

"Bending test pieces shall bend double under the hammer, cold, without signs of cracking.

"In punching test pieces, a row of eight holes, $\frac{3}{4}$ in. in diameter and $1\frac{1}{4}$ ins. between centers, shall be punched without any cracks.

"In drifting test pieces, not less than two holes, $\frac{3}{4}$ in. in diameter, spaced 2 ins. between centers, shall be punched and then enlarged by

blows from a sledge hammer upon a drifting pin until said holes are $1\frac{1}{4}$ ins. in diameter, without showing signs of failure or cracking on the inside of the hole or edge of the plate. Punching and drifting tests to be made cold.

"The plates must also admit of cold hammering or scarfing to a fine edge at the laps without cracking, and the test pieces must furthermore withstand such quenching, forging and other tests as may satisfy the inspector as to the temper, soundness and fitness for use of the material.

"Any failure of test pieces, taken at random as aforesaid, to conform to the above requirements may, at the discretion of the engineer or inspector, cause the rejection of the entire product of the heat or melt from which such pieces are taken.

"All finished material shall be free from laminations, cracks, blisters, scale or cinder spots, and have clean edges and good surface free from bends. The plates shall be fully up to the required thickness at the edges. Any plate whose thickness at any point may be found less than the required thickness by more than one one-hundreth of an inch shall be rejected without appeal. Furthermore, at least 95% of the plates must be of the full required thickness at all points.

"Plates varying more than 5% from the standard weights per square foot will be rejected, and no allowance will be made for weights more than 5% in excess of the standard weights required.

"The plates shall be rolled as flat as good mill practice will permit, and each plate shall be cut to the dimensions required. A variation of more than $\frac{1}{4}$ in. from the dimensions required on either length or width of plate will not be permitted, and in no case shall they be scant of the required dimensions. All material shall be finished in a first-class, workmanlike manner.

"The Engineer of the Power Company, or his representative, shall have the right at all times to inspect the process of manufacture and testing of any and all plates, and may have, in his discretion, an additional number of test pieces, not more than one-fourth of the whole, prepared as above from such melts as he may designate, for testing under his own supervision, at the expense of the power company.

"*Requirements for Steel Rivets.*—Rivets shall be made of a good grade of soft steel, and shall have a tensile strength between the limits of 56 000 lbs. and 64 000 lbs. per square inch, with an elastic limit of not less than 36 000 lbs., and shearing strength not less than 72% of the ultimate strength. Physical tests shall be made by the Inspector to determine the elongation and area at point of fracture. In an ordinary test piece, as described above, the elongation shall be not less than 24%, and the reduction of area at point of fracture not less than 48 per cent. The material shall also be of such quality as will stand bending double and flat, before and after heating to a light yellow heat

and quenching in cold water, without sign of fracture on the convex surface of the bend. All rivet material not conforming to the above requirements shall be rejected.

"It is understood and agreed that any plate that shows any defect during the process of punching, bending, riveting and in manufacturing into pipes shall be rejected, notwithstanding that the same may previously have been satisfactorily tested.

"All plates and rivets must be free from rust and kept under cover from the time of manufacture of the plates and until the completed pipe is dipped or coated. At the factory, the plates must be loaded under cover upon suitably covered cars. They must be delivered under cover at the pipe shop and must be kept under roof and cover until ready for shipment, and in no way exposed to the weather or to moisture. In cases of accidental rusting, the rust must be removed from the plates before proceeding with the manufacture of the pipes.

"*Manufacture and Laying of the Pipe.*—All seams shall be butt seams, with straps exactly fitted to the curvature of the main plates.

"The round straps (uniting adjacent sections) shall be placed on the outside of the pipe only; they shall be 11 ins. wide and their thickness shall be the same as the thickness of the plates in the pipe. Each strap shall have four rows of rivets placed zigzag, and spaced as indicated on the detailed plans.

"The longitudinal seams shall be united by two butt straps, one on the inside and the other on the outside of the pipe. The outer strap shall be 11 ins. wide and the inner $16\frac{1}{2}$ ins.

"The longitudinal joints shall in all cases be placed at the top of the pipe, both in the straight portion and in the elbows, so that the straps shall be entirely continuous throughout the entire length of the pipe.

"The thickness of the longitudinal butt straps (both inside and outside) shall be $\frac{1}{2}$ in. for the portion of the pipe built of $\frac{11}{16}$-in. and $\frac{5}{8}$-in. plates, and $\frac{3}{8}$ in. for the rest of the pipe line.

"There shall be six rows of rivets at the longitudinal joints, of which four rows shall go through both butt straps and the main plate, and two rows through the wider or inside butt strap and the main plate only.

"The spacing shall be zigzag, with a double pitch in the row of rivets that goes through two thicknesses only.

"All butt straps, both longitudinal and circumferential, shall be 'rolled' to the correct circular curve necessary to fit the pipe closely.

"The edges of the outside straps, both round and longitudinal, shall be planed for calking.

"The inside longitudinal butt straps shall be of the same length as

the main plates; they shall be as straight and true as possible, but shall not be calked.

"The outside longitudinal straps, where they butt against the edges of the round straps, shall be planed down to a feather edge for a short distance and extended under the round straps, the edges of the latter being calked.

"The splices in the round straps shall be scarfed joints, extending over three rivets.

"The under strap at the lap must be scarfed or thinned by machinery, without being heated; the upper strap is to remain of the original thickness for calking.

"The diameters of the rivets used shall be as follows:

"For the portion of the pipe line built of—

$\frac{11}{16}$-in. and $\frac{5}{8}$-in. plates..........Diameter of rivet $1\frac{1}{8}$ ins.

of $\frac{9}{16}$-in. and $\frac{1}{2}$-in. plates..........Diameter of rivet 1 in.

of $\frac{7}{16}$-in. and $\frac{3}{8}$-in. plates..........Diameter of rivet $\frac{7}{8}$ in.

"These sizes shall be the diameters of the rivets when cold.

"The rivet holes shall be punched of $\frac{1}{16}$ in. greater diameter than that of the cold rivet, except in the case of the $1\frac{1}{8}$-in. rivets. In this latter case, the rivet holes shall be punched of $1\frac{1}{8}$-in. diameter on the die side and reamed to $1\frac{3}{16}$ ins.

"All riveting in the shop must be done by steam, compressed air or hydraulic machinery, capable of exerting slow pressure sufficient for the formation of perfect rivet heads, of such form and dimensions as may be directed by the engineer.

"All burrs, caused by punching, on the lower side of the plate, must be removed by countersinking; all burrs produced by shearing must be removed by filing or chipping.

"The sheets must be pressed closely together while the rivets are being driven and until the rivet heads are formed. The riveting will be inspected by the Engineer of the Power Company, and all rivets which do not properly fill the holes, or which may be found defective in any respect, must be cut out and replaced by and at the expense of the contractor.

"All riveted seams and joints of every description shall be thoroughly calked on the outside of the pipe in the best and most workmanlike manner usual in first-class boiler work. The calking of all seams made in the shop must be done before the coating is applied in the pipe, and every precaution must be taken, both in the shop work and field work, to insure the utmost strength and tightness."

APPENDIX B.

DESIGNS FOR A STRUCTURAL STEEL DAM.

Two types, Plans A and B, are shown in the plans, out of a number considered, which were studied in detail, so that the quantities of material may be relied upon as correct.

Plan A.—This form of dam consists of a number of cantilever trusses spaced 10 feet apart and braced together, and a steel plate

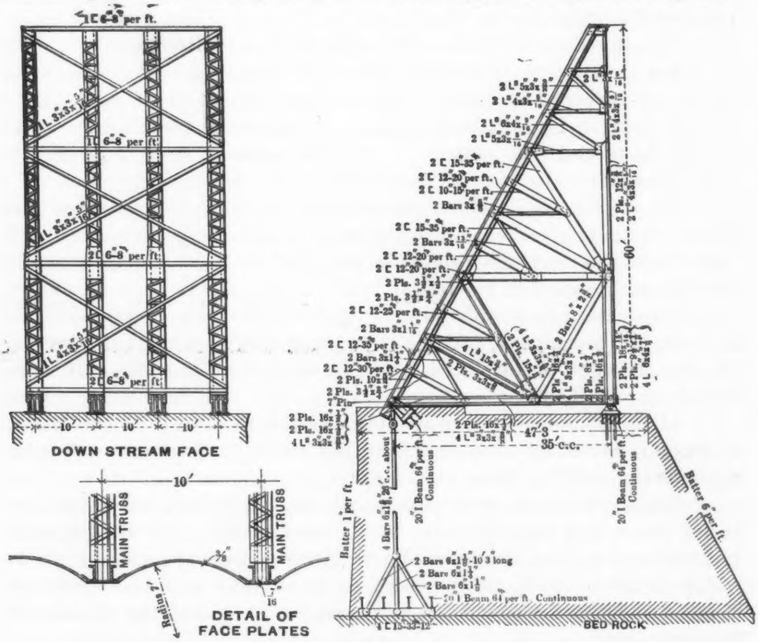

FIG. 16.

covering, which receives the direct water pressure and transmits it to the trusses. The latter are 60 ft. in length, with a base 35 ft. in width, this being nearly the same as the thickness of a standard masonry dam at the same elevation. The construction is shown in Fig. 16.

The outline of the trusses is triangular, the down-stream posts being vertical, while the water face has a heavy batter, as the vertical component of the water pressure on the up-stream face is essential to the stability of the dam. Theoretically, a curved face would lighten the steel work slightly, but not enough to outweigh the advantages of a straight chord.

The steel work rests on a concrete or rock foundation, to which it is securely anchored. This foundation need not be essentially different in size or shape from the equivalent portion of an all-masonry dam, so in comparing relative costs only the upper 60 ft. need be considered.

The trusses are designed according to ordinary bridge practice, with simple details, the connections in the upper portion being by rivets, and in the lower part by turned pins. They should be built according to the specifications for materials and workmanship used for the highest grade of railway bridgework.

The stresses in the different members were determined graphically, the only forces acting being the water pressure, the weight of the dam, and the resistance of the anchorage. All these forces are definite in magnitude and direction to a greater degree than in most other kinds of steel construction.

The tensile stresses were taken at 15 000 lbs. per square inch of net section, while for compression the following formula was used, viz.:

$S = 12\,000 - 45\,\frac{L}{R}$ in which S is the permissible strain per square inch; L is the full length of compression member, and R is the radius of gyration of the cross-section.

Where beams are subject to cross-bending, the net tensile strains are 15 000 lbs. per square inch.

The trusses are braced together in sets of four by comparatively light bracing in the plane of the vertical posts. The long horizontal bottom struts are also connected by bracing. Every fourth panel is left without bracing, so that longitudinal expansion may take place without straining the metal anywhere, the convex plates in the water face allowing a slight motion. Expansion at right angles to the face is provided by short rocking links at the foot of the vertical posts.

Two forms of plate facing were proposed, the first consisting of buckle plates resting on rolled I-beams, while in the second a single curved sheet of steel, extending from one truss to the next, sustains the water pressure. The strength of the buckle plates and beams is computed by the usual methods, the thickness of the former varying according to the depth.

The concave sheets in the second design are circular segments with a radius of 7 ft. and a 10-ft. chord. All sheets are of the same size, and joined to adjoining sheets by calked riveted joints.

These plates are uniformly $\frac{3}{8}$ in. in thickness. Their strength is readily calculable, as the water pressure is constant at any given elevation and the tensile strain is given by the formula: $T = pR$ as in the case of circular arches. For a depth of 60 ft., $p = 60 \times 62.5 = 3\,750$ lbs. per square foot, and $T = 3\,750 \times 7 = 26\,250$ lbs.; hence the gross tensile strain on a $\frac{3}{8}$-in. plate will be only 5 830 lbs. per square inch.

The steel trusses are connected to the foundation by anchor bars on the up-stream end, while the vertical posts rest on steel bed-plates and shoes. The horizontal shear is transmitted by special inclined struts.

Plan B.—This design is based on F. H. Bainbridge's patent, dated April 16th, 1895. The structural frame is not a truss or cantilever, but consists simply of a series of struts which carry the thrust of the water direct to the foundation. These long struts are, of course, securely braced, so as to prevent buckling in any direction. The steel facing consists of buckle plates or concave sheets of steel as already described, which are fastened to an inclined chord to which the struts

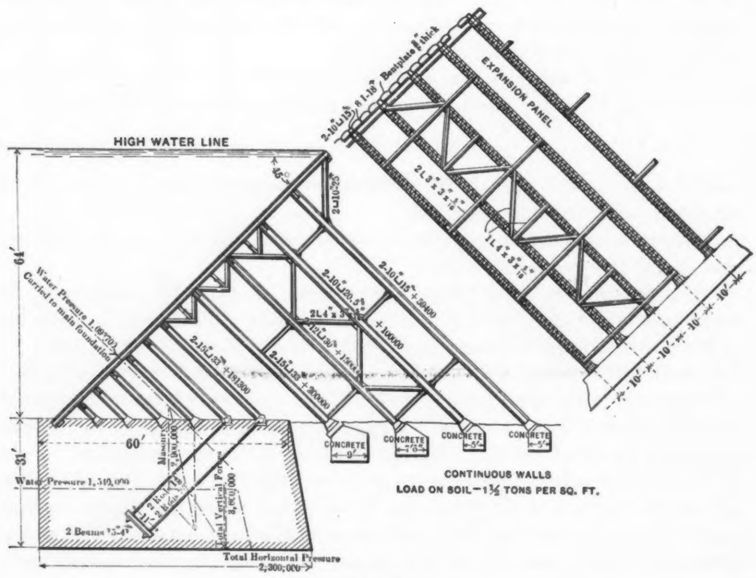

FIG. 17.

connect. The struts and the steel face are both placed at an angle of 45°, with the horizon, so that there is no uplifting effect on the foundation below. The amount of steel in this dam is less than in Plan A, though the saving will be in most cases more than offset by the increased cost of the foundation.

In Fig. 17, the struts are shown as supported on separate shallow foundations, but in most cases, it will be necessary to carry them down to bed-rock, which would increase the amount of masonry very much. On the other hand, where the bed of the stream consists of solid rock, or is overlaid by a small amount of earth, no special

foundation will be required. In such a location, this form of dam may prove economical, and might be adopted with advantage.

The relative amount of materials required to build steel dams, according to Plans A and B, is given in Table No. 2, as well as the amount of masonry contained in a standard masonry dam of the usual form. The comparison is limited to a dam 60 ft. in height, but the metal required for a proper anchorage of the steel dam is taken into account.

TABLE No. 2.—Comparative Statement of Quantities in Steel and Masonry Dams.

Height of dam, 60 ft.; length assumed, 1 ft.

Plan A.—Steel Cantilever Dam with Buckle Plate Facing.

Trusses and bracing	4 530 lbs.	
Shoes, bed-plates and anchorage	1 805 "	
I beams	1 180 "	
Buckle plates	1 285 "	
		8 800 lbs. per lineal foot.

Plan A.—Steel Cantilever Dam with Curved Plate Facing.

Trusses and bracing	4 745 lbs.	
Shoes, bed-plates and anchorage	1 805 "	
Curved face plates	1 500 "	
		8 050 lbs. per lineal foot.

Plan B.—Steel Strut Dam with Buckle Plate Facing.

Total steelwork .... 7 650 lbs. per lineal foot.

Plan B.—Steel Strut Dam with Curved Plate Facing.

Total steelwork .... 7 000 lbs. per lineal foot.

Standard Masonry Dam, 60 ft. high.

Total masonry = 48 cu. yds. per lineal foot of dam.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will hereafter be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

THEODORE G. ELLIS, M. Am. Soc. C. E.*

DIED JANUARY 9TH, 1883.

Theodore G. Ellis received his early technical training in the office of a Boston civil engineer, where he was engaged in minor capacities on a number of railroad surveys. In 1854 he moved to Connecticut to accept an appointment as Assistant Engineer of the Hartford, Providence and Fishkill Railroad. He was placed in charge of a surveying party, and afterwards of the construction of the line from Bristol to Plymouth. When this engagement was completed, he visited Mexico to report on mining properties for Boston parties, and one of his papers before the Society contains a description of the Mexican method of making hard lime floors which he observed during his trip.†

On returning to the United States in 1861 he opened an office in Hartford, Conn., as a surveyor. The next year he enlisted in the Fourteenth Connecticut infantry and served in many engagements during the civil war, among them Chancellorsville, Antietam and Cold Harbor. He was frequently promoted, and before the close of the war had been breveted Brigadier-General.

When peace was restored, General Ellis returned to Hartford and resumed his engineering work. He was engaged in 1867 to make a reconnaissance of such portions of the Connecticut River below Hartford as required improvement, and in this manner became connected with the hydraulic works on which his reputation was chiefly founded. He was engaged on the improvements of this river for many years, and it was during this work that he invented the current meter bearing his name.

One of his best known experimental works was the investigation of the flow of water through large orifices, which he conducted during the summer of 1874 at Holyoke, Mass., with the assistance of Stephen Holman, F. Am. Soc. C. E. This work was described in a paper‡ read before the Society, which was awarded the Norman Medal, being the second to receive that distinction.

General Ellis was elected a Member of the American Society of Civil Engineers on February 17th, 1869, and a Fellow on November 21st,

* Memoir prepared from papers on file at the House of the Society.

† See *Transactions*, Vol. ii, p. 179.

‡ See *Transactions*, Vol. v, p. 19.

1872. He was Vice-President from November, 1873, to November, 1877, and a Director during 1878. He served on many committees of the Society. Among them were two appointed to investigate the failure of dams at Mill River and Worcester respectively, his associates on the committee for the first being James B. Francis and William E. Worthen, and on the second David M. Greene and William W. Wilson. In December, 1875, he was appointed Chairman of a Committee on "American Engineering at the Centennial Exposition," which was subsequently enlarged and changed to the Centennial Commission of the American Society of Civil Engineers. At the eighth convention of the Society, held at Philadelphia during the Centennial Exposition, he delivered the opening address, which was entitled "The Rise and Progress of American Engineering."*

He was a frequent contributor to the professional discussions of the Society and presented the following papers in addition to those previously mentioned: "The Aneroid Barometer and its Use in Estimating Altitudes," Volume I, page 277; "Experimental Strains upon a Bowstring Trussed Girder," Volume II, page 107; "Causes of Formation of Bars at River Mouths," Volume II, page 23; "The Flow of Water in Open Channels," Volume VI, page 250.

General Ellis died at Hartford, Conn., on January 9th, 1883, in his fifty-third year.

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*See *Proceedings*, Vol. ii, p. 13.

CHARLES LE GRAND McALPINE, M. Am. Soc. C. E.*

Died January 11th, 1884.

Charles Le Grand McAlpine was born in Albany, N. Y., and was educated at the well-known Albany Academy. For many years he was in the Engineer Department of the State of New York and filled various positions of responsibility in the reconstruction and enlargement of the Erie and other canals of that State. He was also in charge of the construction of several railroads, and his last active direction of location and construction was of the Albemarle and Raleigh road in North Carolina, now a part of the Atlantic Coast line.

His father was connected with the construction of some of the first railway and canal works in the United States, and was associated with John B. Jervis, Hon. M. Am. Soc. C. E., in the construction of the Delaware and Hudson Canal and Railroad. The elder brother of Charles was William Jarvis McAlpine, the third President of the Society, and afterwards an Honorary Member. His extended professional works and his aggressive individuality have made his name notable among American civil engineers. Charles was of a more retiring disposition, with much reserve and dignity of character. With a large experience and a trained judgment in engineering problems, he never sought notoriety. He was, however, a capable adviser in works of importance, and his aid and counsel as consulting engineer were constantly sought by managers and investors in large undertakings.

For a number of years he lived in the city of New York, acting as consulting engineer. He died in that city, January 11th, 1884. His widow was the daughter of the late Thomas Farrington of Tioga County, N. Y. Mr. McAlpine became a member of the Society December 4th, 1867.

* Memoir prepared by John Bogart, M. Am. Soc. C. E.

JOSEPH RUSSELL THOMAS, M. Am. Soc. C. E.*

Died November 28th, 1896.

Joseph Russell Thomas was first actively engaged in engineering works during the period when the construction of American gas works was passing from the control of British contractors to those of this country. He was born in Burlington, N. J., on March 11th, 1820, and was educated in the Philadelphia public schools. He learned the trade of a carpenter, but abandoned it to engage in the grocery business. About this time the Camden Iron Works, at Camden, N. J., were started by Messrs. J. W. & J. F. Starr, who placed the gas division of their establishment under the charge of Samuel A. Thomas, an elder brother of the subject of this memoir. It was through the influence of this brother that Joseph A. Thomas was engaged on a Starr contract for vessels under construction at Hoboken. When the work was finished, he entered the employ of Messrs. Stevens of that place, and was engaged on the construction of the "Stevens battery."

By this time, however, the gas business of the Camden works had increased to an unexpected extent, and Mr. Thomas believed that it was destined to still greater development. In 1848 he moved to Camden and entered the employ of the firm. His spare moments were spent in studying engineering subjects, and his aptitude for applying theory to practice soon led to his appointment as superintendent of construction of the firm's contract.

His first undertaking was the erection of the plant of the New York Gas Light Company on the East River between Twenty-first and Twenty-second Streets to replace an old plant which was located at Center and Hester Streets. The work was carried on in 1850–51, being interrupted during the winter by the erection of a gas plant at New Brunswick, N. J., of which Mr. Thomas was likewise superintendent of construction. When these works were finished, he built the plant at Norfolk, Va., for the same contractors.

Somewhat later Mr. Lemuel Davis, of Detroit, Mich., engaged him to rebuild the gas works in that city. These works had been in operation a short time, but had already proved inadequate to the demands of the city, which was growing rapidly. When the work of remodeling the plant was completed in 1852, Mr. Davis is reported to have been so satisfied with the manner in which the undertaking was carried through that he added a substantial bonus to the amount due Mr. Thomas. By this time the latter had achieved a good position among gas engineers, and his services were in considerable demand. He

* Memoir prepared from papers on file at the House of the Society.

finally became associated again with Mr. J. W. Starr, this time in connection with the Williamsburgh Gas Light Company.

In 1854, when Mr. Thomas was elected engineer and superintendent of this company, Williamsburgh was a straggling suburb of Brooklyn, N. Y., occupying such land as rose above the marshes north of the latter city. It was not a pleasant place and seemed destined to grow slowly. The local gas works was apparently in keeping with the territory it supplied. It is reported to have been an ill-located, ramshackle affair, steadily drifting toward insolvency. The new superintendent had received at Detroit a good preliminary training for the management of such a plant, however, and he soon had affairs on a satisfactory business basis. Williamsburgh and Brooklyn were united politically, and the marshes between the two districts were filled in. The demand for gas increased rapidly, and under the direction of Mr. Thomas, who was elected a director of the company in 1855, the plant was reconstructed and enlarged until it became one of the best known for completeness of equipment in the country.

In 1883 he severed his active connection with the company's affairs, and became the editor of the *American Gas Light Journal*, a position he held until his death. He also continued his extensive practice as consulting engineer, among his most notable engagements being the design and construction or reconstruction of the plants at Flushing, College Point, Jamaica, Fishkill, Tarrytown, Sing Sing and Poughkeepsie, N. Y., and Long Branch, N. J. The works at the last place he not only built, but also operated for a time until it was in good condition financially.

Although afflicted with serious deafness in his later years, he never lost his interest in the public affairs of Williamsburgh, and was a trustee for many years of the Williamsburgh Public Dispensary, and the Williamsburgh Public Library Association, and was one of the most liberal patrons of the Brooklyn Art Association. He was elected a Member of the American Society of Civil Engineers on October 5th, 1881, and was, in addition, a member or honorary member of the New England Association of Gas Engineers, the Western Gas Association, the Ohio Gas Association, the Guild of Gas Managers and the American Gas Light Association.

Mr. Thomas died at his country home at Glen Ridge, N. J., on November 28th, 1896, after a long illness. His wife and a daughter survived him.

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Vol. XXIII. AUGUST, 1897. No. 6.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publication.

CONTENTS.

SOCIETY AFFAIRS.

PAPERS.

ILLUSTRATIONS.

The price of publications is as follows: Proceedings, $6 per annum; Transactions, $10 per annum. Postage will be added when they are sent to foreign countries.

American Society of Civil Engineers.

OFFICERS FOR 1897.

President, BENJAMIN MORGAN HARROD.

Vice-Presidents.

Term expires January, 1898:
WILLIAM R. HUTTON,
P. ALEXANDER PETERSON.

Term expires January, 1899:
GEORGE H. MENDELL,
JOHN F. WALLACE.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOHN THOMSON.

Directors.

Term expires January, 1898:
AUGUSTUS MORDECAI,
CHARLES SOOYSMITH,
GEORGE H. BENZENBERG,
GEORGE H. BROWNE,
ROBERT CARTWRIGHT,
FAYETTE S. CURTIS.

Term expires January, 1899:
GEORGE A. JUST,
WM. BARCLAY PARSONS,
HORACE SEE,
JOHN R. FREEMAN,
DANIEL BONTECOU,
THOMAS W. SYMONS.

Term expires January, 1900:
JAMES OWEN,
RUDOLPH HERING,
HENRY G. MORSE,
BENJAMIN L. CROSBY,
HENRY S. HAINES,
LORENZO M. JOHNSON.

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THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:
HORACE SEE,
WM. BARCLAY PARSONS,
F. S. CURTIS,
JOHN R. FREEMAN,
JAMES OWEN.

On Publications:
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ROBERT CARTWRIGHT,
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JOHN F. WALLACE,
HENRY S. HAINES.

On Library:
AUGUSTUS MORDECAI,
DANIEL BONTECOU,
CHARLES WARREN HUNT,
WM. BARCLAY PARSONS,
HENRY G. MORSE.

Special Committees.

ON UNIFORM STANDARD TIME:—Sandford Fleming, Charles Paine, Theodore N. Ely, J. M. Toucey, T. Egleston.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf, Thomas Rodd, A. E. Hunt.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath Charles B. Dudley, Alexander C. Humphreys.

The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—127 EAST TWENTY-THIRD STREET, NEW YORK.

Vol. XXIII. AUGUST, 1897. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

June 2d, 1897.—The meeting was called to order at 20.15 o'clock, Vice-President Hutton in the chair; Chas. Warren Hunt, Secretary, and present, also, 88 members and 6 visitors.

The minutes of the meetings of May 5th and 19th were approved as printed in *Proceedings* for May, 1897.

A paper entitled, "The Distortion of Riveted Pipe by Back-Filling," by D. D. Clarke, M. Am. Soc. C. E., was presented by the Secretary, who read correspondence on the subject from H. D. Bush, M. Am.

Soc. C. E. The paper was discussed orally by B. R. Green, Clemens Herschel, James Owen, O. F. Nichols, Henry Goldmark and A. S. Tuttle.

Ballots were canvassed and the following candidates declared elected:

As Members.

Eugene Carroll, Butte, Mont.
Henry Fiddeman Lofland, Wilmington, Del.
Theodore Alfred Leisen, Wilmington, Del.
Theron Agustus Noble, Seattle, Wash.
William Luther Sibert, Little Rock, Ark.

As Associate Members.

Elstner Fisher, Jackson, Mich.
Ira Grant Hedrick, Kansas City, Mo.
Leonard Sewall Smith, Madison, Wis.
William Barksdale Tabb, Louisville, Ky.
Joseph Bodine Wright, New York City.

The Secretary made an announcement of the arrangements for the Annual Convention so far as they were settled, and Mr. George A. Just, Chairman, made a brief report for the Building Committee on the progress of the work on the New Society House.

Adjourned.

TWENTY-NINTH ANNUAL CONVENTION, HELD AT QUEBEC JUNE 30th to JULY 2d, 1897.

The members assembled at 10 o'clock, June 30th, 1897, in the Council Chamber of the City Hall, Quebec. They were welcomed on behalf of the City of Quebec by Pro-Mayor Norris, who introduced his Honor the Lieutenant-Governor of the Province of Quebec, Sir Adolphe Chapleau, and the Honorable Felix Marchand, Premier of the Province. After addresses of welcome * by these gentlemen, to which President B. M. Harrod replied, the meeting of the Society was convened.

First Session, Wednesday Morning, June 30th, 1897.—The Society met at 11 o'clock, President B. M. Harrod in the chair; Charles Warren Hunt, Secretary.

President Harrod read the annual address of the President,† and afterwards invited, in the name of the Society, the Lieutenant-

* See p. 124.
† See *Transactions*, Vol. xxxvii, p. 537.

Governor, Premier, and all the officers of the Province and City to attend the meetings of the Convention.

On motion by Mr. Morison, duly seconded, it was voted to extend the thanks of the Society to the Lieutenant-Governor and the Premier for the cordial manner in which they greeted it.

The Secretary made several announcements concerning changes in the programme.

A paper by A. C. Cunningham, M. Am. Soc. C. E., entitled "The Relation of Tensile Strength to Composition in Structural Steel," was presented by the Secretary, who read correspondence on the subject from Messrs. H. H. Campbell and J. A. L. Waddell. The paper was discussed by Messrs. William Metcalf, Henry B. Seaman and Joseph Mayer.

A paper by J. E. Greiner, M. Am. Soc. C. E., entitled "Recent Tests of Bridge Members," was presented in abstract by the Secretary, who read correspondence on the subject from Messrs. G. H. Thomson, C. M. Broomall and John C. Moses. The paper was discussed by Messrs. S. Bent Russell, J. P. Snow, J. B. French, George S. Morison and R. S. Buck.

On motion, duly seconded, it was voted that the order of business at 10.30 o'clock on July 1st should be the consideration of the proposed amendments to the Constitution.

A recess was taken until 14.30 o'clock.

Second Session, Wednesday Afternoon, June 30th, 1897.—The meeting was called to order at 14.30 o'clock, President Benjamin M. Harrod in the chair; Charles Warren Hunt, Secretary.

A paper entitled "The Power Plant, Pipe Line and Dam of the Pioneer Electric Power Company, at Ogden, Utah," was presented by Henry Goldmark, M. Am. Soc. C. E., and discussed by Messrs. F. W. Skinner, J. P. Frizell, Robert Moore and Henry Goldmark. Communications on the subject from Messrs. R. F. Heywood and D. C. Henny were presented by the Secretary.

Sandford Fleming, M. Am. Soc. C. E., presented a statement of the work of the Society and other organizations in the matter of time reform. On motion, duly seconded, the communication from Mr. Fleming was received as a progress report of the Committee on Uniform Standard Time.* The following resolution, introduced by Mr. Fleming, was then passed:

"*Resolved*, That the Directors of the Society be authorized and requested to take such steps as may appear to them advisable to move

* This communication will be found on p. 128.

the Government of the United States to accept the sixth resolution of the Washington Prime Meridian Conference of 1884, in order that the proposed change shall take effect on the first day of the new century."

E. P. North, M. Am. Soc. C. E., presented a communication from J. W. Conrad, Esq., President of the Permanent Commission of the International Congress of Internal Navigation, announcing that the seventh Congress will be convened at Brussels, Belgium, in August, 1898.

E. A. Fuertes, M. Am. Soc. C. E., presented a communication describing the hydraulic laboratory at Cornell University, and offering its facilities to engineers desiring to investigate hydraulic problems.*

President Harrod appointed provisional chairmen from each geographical district into which the membership is divided, for the purposes of the Nominating Committee (Art. VII, Sec. 2, of the Constitution).

Adjourned.

BUSINESS MEETING.†

Thursday, July 1st, 1897.—The Business Meeting was called to order at 10 o'clock, President B. M. Harrod in the chair; Charles Warren Hunt, Secretary.

The minutes of the meeting of June 2d, 1897, were read and approved.

The Secretary announced the appointment by the Board of Direction of the following members as a special committee to report on the proper manipulation of tests of cement: George F. Swain, Alfred Noble, George S. Webster, O. M. Carter, W. B. W. Howe, Louis C. Sabin and H. W. York.

The Secretary presented the report of the Committee on the Award of the Collingwood Prize for Juniors, awarding the prize to H. W. York for Paper No. 779; and the new rules governing the award of the Society's endowed prizes.‡

The Secretary announced the election by the Board of Direction on May 4th, 1897, of the following Honorary Members: Sir Benjamin Baker, of London, England, and Professor George Davidson, of San Francisco, Cal.

Resolutions were passed in recognition of the fact that the Society was holding its session on Dominion Day, and acknowledging the courtesies extended to it during the Convention.§

The Secretary presented a summary of the answers received in

* The full text of Professor Fuertes' statement is given on p. 133.

† For full report, see p. 87.

‡ See page 88.

§ See pages 121 and 122.

respect to the time and place of holding the next Annual Convention, and on motion, duly seconded, the matter was referred to the Board of Direction with power.

The three following proposed amendments to the Constitution, having been received and sent to the Corporate Members in accordance with Article IX, Section 3, of the Constitution, were taken up:

AMENDMENT No. 1.

Erase from Section 1 of Article V of the Constitution, the words:

"with all living Past-Presidents of the Society who continue to be members,"

and at the end of said section add the following words:

"All living Past-Presidents of the Society, who continue to be members, shall be entitled to be present at all meetings of the Board of Direction, and to discuss all questions coming before the Board and aid the Board by their advice and counsel; but said Past-Presidents shall not have a right to vote, nor shall their presence be requisite in order to constitute a quorum."

So that said Section 1 of Article V shall read as follows:

Article V.—Officers.

"1.—The Officers of the Society shall be: A President, four Vice-Presidents, eighteen Directors, a Secretary, and a Treasurer, who shall constitute the Board of Direction, in which the government of the Society shall be vested, and who shall be the Trustees as provided for by the laws under which the Society is organized. All living Past-Presidents, who continue to be members, shall be entitled to be present at all meetings of the Board of Direction, and to discuss all questions coming before the Board and aid the Board by their advice and counsel; but said Past-Presidents shall not have a right to vote, nor shall their presence be requisite in order to constitute a quorum."

Proposed by ..... Julius W. Adams, Henry Flad, George S. Greene, Thomas C. Keefer, Charles Paine, William Metcalf, D. J. Whittemore, Thomas Curtis Clarke.

AMENDMENT No. 2.

Strike out Section 1 of Article V and substitute for it the following section:

"1.—The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Treasurer, and a Secretary. The President, Vice-Presidents, Directors and Treasurer shall be the Trustees as provided by the laws under which the Society is organized. The President, Vice-Presidents, Directors, Treasurer, and all living Past-Presidents of the Society who continue to be members, shall constitute the Board of Direction in which the government of the Society shall be vested."

Proposed by...... George S. Morison, John Bogart, William P. Craighill, Joseph M. Wilson, William H. Burr.

AMENDMENT No. 3.

Amend Section 1 of Article V of the Constitution so that it shall read as follows:

"The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Treasurer, and a Secretary. The President, Vice-President, Directors and Treasurer shall be Trustees as provided for by the laws under which the Society is organized. The President, Vice-Presidents, Directors, Treasurer and all living Past-Presidents of the Society, who shall continue to be Members, shall constitute the Board of Directors in which the government of the Society shall be vested."

Proposed by......	ROBERT MOORE,	W. S. LINCOLN,
	E. D. MEIER,	ROBERT E. McMATH,
	CARL GAYLER,	M. L. HOLMAN.

Upon motion, duly seconded, amendment No. 1 was amended by a vote of 110 to 6 to read as follows:

ARTICLE V.—OFFICERS.

"1.—The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Secretary, and a Treasurer, who, with the five latest living Past-Presidents, who continue to be members, shall constitute the Board of Direction in which the government of the Society shall be vested, and who shall be the Trustees as provided for by the laws under which the Society is organized. For the election of Honorary Members all the Past-Presidents shall be members of the Board of Direction, except any Past-President who may be disqualified by mental or bodily infirmity, and the evidence of said disqualification shall be a written certificate from his attending physician, or some officer of the Society."

It was moved, seconded and carried by a vote of 92 to 15 that amendments Nos. 2 and 3 be changed so as to conform in every respect precisely with amendment No. 1 as amended.

Nominations were received for members of the Nominating Committee from each of the seven geographical districts, and the following were elected members of the Committee for two years:

District No. 1, Henry B. Seaman; District No. 2, E. H. Keating; District No. 3, Edward W. Howe; District No. 4, J. N. Chester; District No. 5, Gouverneur Morris; District No. 6, James Dun; District No. 7, A. M. Scott.

George A. Just, M. Am. Soc. C. E., presented a report of a Special Committee of the Board of Direction on the condition of the New Society House.*

Adjourned.

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* See page 122.

OF THE BOARD OF DIRECTION.

(Abstract.)

June 1st, 1897.—Eight members present.

New rules were adopted governing the award of prizes.*

The election as Honorary Members of Sir Benjamin Baker, London, England, and Professor George Davidson, San Francisco, Cal., was announced.

William Starling, Randall Hunt and the Secretary were appointed a committee to award the Collingwood Prize for Juniors.

A committee was appointed to prepare a report on the condition of the New Society House, etc., to be presented to the Business Meeting of the Convention.

The President, Secretary, Treasurer and the Chairmen of the Finance and Building Committees were appointed a committee to make all arrangements for the formal opening of the New Society House.

Applications were considered and other routine business transacted.

Adjourned.

July 1st, 1897.—Thirteen members present.

A Committee was appointed to confer with members of the Society in Detroit, and to report to the Board as to the best time and place for holding the next Annual Convention.

Adjourned.

REPORT IN FULL OF THE BUSINESS MEETING HELD DURING THE ANNUAL CONVENTION AT QUEBEC, CANADA, JULY 1st, 1897.

The meeting was called to order at 10 A. M., President B. M. Harrod in the chair; Charles Warren Hunt, Secretary. **Meeting called to order.**

The PRESIDENT.—The meeting is called at 10 o'clock. A special order of business is fixed for 10.30. The Society is now in session, and the preliminaries of minutes and other matters will be disposed of before 10.30.

The Secretary read the minutes of the last Business Meeting of the Society, held June 2d, 1897.

The PRESIDENT.—You have heard the minutes of the last Business Meeting of the Society read. Are there any amendments? If there are none, the minutes will be approved.

The SECRETARY.—I have to report that on April 7th, 1897, the Society authorized the appointment of a special committee to report **Appointment of Committee on Manipulation of Cement Tests.**

* See p. 88.

on the proper manipulation of tests of cement, and the Board of Direction has appointed the following gentlemen as such committee: Messrs. George F. Swain, Alfred Noble, George S. Webster, O. M. Carter, W. B. W. Howe, Louis C. Sabin and H. W. York. The committee has not as yet organized, and no chairman of the committee was appointed by the Board.

The report of the Committee to award the Collingwood Prize for Juniors is as follows:

REPORT OF THE COMMITTEE TO AWARD THE COLLINGWOOD PRIZE FOR JUNIORS.

Report on Collingwood Prize for Juniors.

The Committee appointed to award the Collingwood Prize for Juniors respectfully reports that it has unanimously awarded this prize for the year terminating December 31st, 1896, to Paper No. 779, entitled "The Twenty-eighth Street Central Station of the United Electric Light and Power Company," by Herbert Waldo York, Jun. Am. Soc. C. E.

The Committee begs to add, in order to avoid confusion, that since the date of the presentation and publication of the paper Mr. York has been transferred to the grade of Member.

Respectfully submitted,

Wm. Starling.
Randall Hunt.
Chas. Warren Hunt.

June 3d, 1897.

Election of Honorary Members.

I have also to announce the election by the Board of Direction as Honorary Members of the Society, on May 4th, 1897, of Sir Benjamin Baker, of London, England, and of Professor George Davidson, of San Francisco, California.

The Board of Direction has, with the consent of the donors of the three prizes, adopted a new set of rules for their award, which is as follows:

RULES GOVERNING AWARD OF PRIZES.

Prizes.

New Rules Governing Prizes.

There are at present three endowed prizes for papers published in the *Transactions* of the American Society of Civil Engineers. These prizes are awarded annually.

With the assent and the approval of the donors, by action of the Board of Direction, June 1st, 1897, the Society assumes the responsibility for the payment in perpetuity of the Norman Medal, Thomas Fitch Rowland Prize and Collingwood Prize.

Committee on Prizes.

1. The Board of Direction shall appoint annually, not later than its regular meeting in June of each year, three Corporate Members of the Society, not members of the Board of Direction, who shall form a Committee to recommend the award of all prizes during the year.

2. The papers considered shall include all papers published in the *Transactions* during the year ending with the month of July.

3. The Committee on Prizes shall report its recommendation to the Board of Direction on or before December 31st, and the awards shall be made by the Board of Direction.

4. The announcement of the awards shall be made at the Annual Meeting.

5. The Secretary of the Society shall act as Secretary to the Committee on Prizes, but shall have no vote or voice in its deliberations.

CODE OF RULES.

The Norman Medal.—The Norman Medal was instituted and endowed in 1874 by George H. Norman, M. Am. Soc. C. E.

I. Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to members of the Society.

II. There shall be one gold medal awarded as hereinafter provided. The dies therefor shall be deposited with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such medal shall be of a value of $60.

III. All original papers presented to the Society by members of any class, and published in the *Transactions* during the year for which the medal is awarded, shall be open to the award, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been published in the *Transactions* in any previous year.

IV. The medal shall be awarded to a paper which shall be judged worthy of special commendation for its merit as a contribution to engineering science.

The Thomas Fitch Rowland Prize.—The Thomas Fitch Rowland Prize was originally instituted by the Society at the Annual Meeting in 1882. It was endowed in 1884 by Thomas Fitch Rowland, M. Am. Soc. C. E. Its award is not restricted to members of the Society.

I. The prize shall consist of $60 in cash, with an engraved certificate signed by the President and Secretary of the Society.

II. In the award of this prize preference shall be given to papers describing in detail accomplished works of construction, their cost and errors in design and execution.

The Collingwood Prize for Juniors.—The Collingwood Prize for Juniors was instituted and endowed in 1894 by Francis Collingwood, M. Am. Soc. C. E.

I. The competition for the prize shall be restricted to the Juniors of the Society.

II. The prize shall consist of $50 in cash, with an engraved certificate, signed by the President and the Secretary of the Society.

III. The prize shall be awarded to a paper describing an engineering work with which the writer has been directly connected, or it shall record investigations contributing to engineering knowledge, some essential part of which was made by the writer, and contain a rational digest of results. Any mathematical treatment must show immediate adaptability to professional practice. Accuracy of language and excellence of style will be factors in the award.

IV. These rules may be modified by the Board of Direction.

Mr. President, these are all the announcements that I have to

make. If there is time, it might be well to read the report of answers received as to time and place of holding the next annual Convention.

The PRESIDENT.—There are fifteen minutes left before the order of business comes up, which affords time for——

Announcement Concerning Dominion Day.

WILLIAM P. CRAIGHILL, Past-President Am. Soc. C. E.—Permit me to say a word or two. This, as I understand, is a day which is considered among Canadians as the equivalent of the Fourth of July with us, and it seems to me that it would be very appropriate for this Society in some way, as we are in a measure the guests of the country at this time, to recognize that fact, and I therefore move that the President appoint a committee of three to draft a suitable resolution on that subject, expressive of the good will of this Society for the Dominion of Canada on its birthday. (Seconded.)

The PRESIDENT.—You have heard General Craighill's motion, gentlemen, which is seconded. I presume there is no discussion and that you are ready for the question. All who are in favor of the motion will signify their consent by saying aye; contrary minded, no.

The motion was carried.

Vote on Time and Place of next Convention.

The PRESIDENT.—I will appoint the committee in five minutes. The Secretary will now read the answers that have been received, relative to the next Convention.

The Secretary read the following summary of the answers received in respect to the time and place of holding the next Convention:

Fifty votes in all for the place of the Convent[illegible] were received.

Mackinaw	6	Chicago	3
Quebec	5	Nashville	3
Washington	4	New York	3
Buffalo	4	Atlantic City	3
St. Louis	3		

The remainder were scattering.

Fifty-four votes for the time of the Convention were received.

During the month of June	11	During the month of July	9
During the last part of June	14	July 15th	6
During the month of August	5		

The remainder were scattering.

The PRESIDENT.—I will appoint as the committee which has been authorized to prepare resolutions relative to the Dominion's Fourth of July, General Craighill, Mr. Stearns and Mr. Starling.

Discussion on Time and Place of next Convention.

In the few minutes that remain, it might be well to discuss this matter of the next Convention. I will lay that before you for ten minutes, when the regular order of business will be called up. I would like to say, in the beginning, that for just twenty years there has not been a convention held south of Chattanooga, and I think it belongs to us down there the next time.

George Y. Wisner, M. Am. Soc. C. E.—Mr. President: On behalf of the civil engineers of Michigan and of the citizens and the commercial bodies and the Mayor of the City of Detroit, I am authorized and requested to earnestly urge that the American Society of Civil Engineers hold its next annual Convention in Detroit. We are in receipt of telegrams from there to urge that as strongly as we can, and to say that they will see that the Convention is a success. We have every hotel facility necessary to make it a success. Our transportation lines leading out of Detroit are such that it is easy of access, and it is also agreeable so far as excursions are concerned. The people there only ask that the Society decide to come, and they will see to it that the Convention is a success and that the members enjoy themselves.

Gouverneur Morris, M. Am. Soc. C. E.—I merely want to add to what Mr. Wisner has just said, that I hope the Society will agree with us and decide to hold its next annual Convention in Detroit, and so far as it lies in my power, and so far as the citizens of Detroit are concerned, it will be made the greatest success that is possible, and I hope it will be the pleasure of the Society or of the Board of Direction to so decide. I would like to add that the Society has never held its Convention in Detroit at all since it has been holding annual conventions, and I think the great middle West at the present time is entitled to the meeting more than any other section of the country. In reference to the remarks of the President about going South: the Convention has been as far south as Chattanooga, and has also been to Fortress Monroe within the past seven years, and I think the great middle West is entitled to it the next time. I don't know a more central location or a place where the Society could enjoy itself better or have better facilities than the city of Detroit.

Joseph Ramsey, Jr., M. Am. Soc. C. E.—I would like to second that motion as representing one of the lines of transportation leading to Detroit, and I would say that any of our western friends who strike the line at Kansas City will be put through on a freight train or some other train which will get them there in time. I would like to extend the courtesies of the Wabash in advance to Detroit or St. Louis or any other place that may be selected.

Mr. Wisner.—I would like to suggest in regard to the list which was read by the Secretary in regard to the number of votes for different places, that it might be well to take a vote of the members present to see the sentiment of the members here in regard to the locality. I make that as a motion.

Mr. Morris.—I second that.

George S. Morison, Past-President Am. Soc. C. E.—As a very simple method of testing the general feeling of this meeting, I would make the motion that the next Convention be held in the extreme south, with the understanding that everybody who votes against it is in favor

Discussion on Time and Place of next Convention (continued).

of Detroit or some other such place. I simply make that motion as the simplest way of getting the sentiment of the meeting here. I make the motion in order to get a test vote.

The President.—Then, as I understand it, there is a nomination, first, of Detroit, by Mr. Wisner; then there is Mr. Wisner's motion that a vote be taken on the matter. That motion has been seconded.

Mr. Morison.—I did not understand that it had been seconded. I withdraw my motion.

The President.—Then, also, Mr. Morison puts in nomination some point in the extreme South, and I understand the vote will turn on Detroit or a point in the extreme South, leaving, of course, the choice to the members to cast any scattering votes they please.

General Craighill.—While I have been in Detroit and know how hospitable the people are and how lovely it would be to go there, it does seem to me that at this stage of the proceedings it would be inexpedient to vote on any particular place, and I should greatly prefer to see that we have a general expression as to the section of the country which we prefer without indicating in any particular way at this time any special point. My feeling is, after the discussion of the matter, to make a motion referring it—as we usually do—to the Board of Direction. They have more information on the subject than we have, and I think they are better able to decide the question, and I think it would be very disagreeable to us to vote down Detroit when we want to go there; so I think it would be better to withdraw that proposition.

Mr. Morris.—I appreciate the force of General Craighill's remarks and also the fact that the whole matter will have to be referred to the Board of Direction. This is merely to get an expression of opinion from the members present as to the locality. I think with Mr. Wisner's consent we can say the Middle West as against the extreme South, and that would cover the point raised by General Craighill, and the whole matter could then be referred to the Board of Direction. It was just to get the opinion of the members present as against the paltry 50 votes that were read for various localities throughout the country.

The President.—Shall that vote be taken *vive voce* or will the members during the day leave a written vote at the Secretary's desk?

(A rising vote was called for.)

Joseph M. Knap, M. Am. Soc. C. E.—I would like to ask what the question is ?

The President.—As I understand now, by the consent of the movers of the original resolution, it is that the Society by a standing vote express a preference for the place of holding the next meeting at a point in the Middle West or in the extreme South. Is that the general understanding ? Very well. All who are in favor of the next

Annual Convention being held at some point in the Middle West rather than the extreme South will please rise.

(Seventy-eight members rose.)

The PRESIDENT.—Now, all who are in favor of holding the meeting at some point in the extreme South rather than in the Middle West will please rise and be counted.

(Fourteen members rose.)

General CRAIGHILL.—Now, Mr. President, as the hour for the standing order is near, I move that the whole subject be referred to the Board of Direction.

Mr. MORISON.—There is one little matter which will take only a moment, which I would like to bring up before this subject is referred. It is simply this: I think, as we are going to hold our Convention in the North, probably in a large city, that it would be well to hold the Convention at a little different time from that at which it is usually held. We have been holding the Convention just at the time of the closing of the college year, so that the educational part of the members find it hard to attend. So I would like to move, in view of the location at which the Convention is probably going to be held, that it be held in the month of August.

HENRY B. SEAMAN, M. Am. Soc. C. E.—Bearing on that question, I think the only feature which influences the date of the Convention is that it shall be just before the opening of the summer season. You cannot take a hotel and monopolize it in the midst of the summer season, and you cannot do it in midwinter unless the hotel is open, or, as it is, we come a week ahead of the opening of the summer season and the hotel is willing to open for that special purpose. I think that consideration has had a large influence in the selection of the dates heretofore.

Mr. MORRIS.—I rather agree with Mr. Morison's idea except as to the time. I should think July would be preferable to August. As far as meeting Mr. Seaman's objection, it will not affect any meeting that may be held in Detroit in regard to hotel accommodations or anything else.

The PRESIDENT.—The motion is to refer the whole matter now to the Board of Direction. There is no time for further discussion. All in favor of that, please say aye; contrary minds, no.

The motion was carried.

The PRESIDENT.—The order of business is now in order. That order consists of certain amendments to the Constitution which appear before this general meeting. The Secretary will read them.

The Secretary read the following proposed amendments:

Proposed Constitutional Amendments read.

AMENDMENT No. 1.

Erase from Section 1 of Article V of the Constitution the words:

Proposed Constitutional Amendments (continued).

"with all living Past-Presidents of the Society who continue to be members,"

and at the end of said section add the following words:

"All living Past-Presidents of the Society, who continue to be members, shall be entitled to be present at all meetings of the Board of Direction, and to discuss all questions coming before the Board and aid the Board by their advice and counsel; but said Past-Presidents shall not have a right to vote, nor shall their presence be requisite in order to constitute a quorum."

So that said Section 1 of Article V shall read as follows:

Article V.—Officers.

"1. The officers of the Society shall be: a President, four Vice-Presidents, eighteen Directors, a Secretary, and a Treasurer, who shall constitute the Board of Direction, in which the government of the Society shall be vested, and who shall be the Trustees as provided for by the laws under which the Society is organized. All living Past-Presidents, who continue to be members, shall be entitled to be present at all meetings of the Board of Direction, and to discuss all questions coming before the Board and aid the Board by their advice and counsel; but said Past-Presidents shall not have a right to vote, nor shall their presence be requisite in order to constitute a quorum."

Proposed by Julius W. Adams, George S. Greene, Charles Paine, D. J. Whittemore, Henry Flad, Thomas C. Keefer, William Metcalf, Thomas Curtis Clarke.

AMENDMENT No. 2.

Strike out Section 1 of Article V and substitute for it the following section:

"1. The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Treasurer, and a Secretary. The President, Vice-Presidents, Directors and Treasurer shall be the Trustees as provided by the laws under which the Society is organized. The President, Vice-Presidents, Directors, Treasurer and all living Past-Presidents of the Society who continue to be Members shall constitute the Board of Direction in which the government of the Society shall be vested."

Proposed by George S. Morison, William P. Craighill, William H. Burr, John Bogart, Joseph M. Wilson.

AMENDMENT No. 3.

Amend Section 1 of Article V of the Constitution so that it shall read as follows:

"The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Treasurer, and a Secretary. The President, Vice-President, Directors and Treasurer shall be Trustees as provided for by the laws under which the Society is organized. The President, Vice-Presidents, Directors, Treasurer and all living Past-Presidents of the Society who shall continue to be Members shall

constitute the Board of Directors in which the government of the Society shall be vested."

Proposed by Robert Moore, E. D. Meier, Carl Gayler, W. S. Lincoln, Robert E. McMath, M. L. Holman.

The PRESIDENT.—In relation to these amendments there has been a communication sent to the Society through the Secretary, signed by a large number of the members of the Society. I would ask the Secretary to read that. **Discussion on Constitutional Amendments.**

The Secretary read the following communication:

Mr. CHAS. WARREN HUNT,
Secretary American Society of Civil Engineers,
127 East Twenty-third Street, New York.

DEAR SIR,—Inasmuch as certain amendments to the Constitution of the American Society of Civil Engineers have been proposed and will be presented for discussion to the Convention at Quebec, and it may not be possible for some of the undersigned to be present to express their views and vote upon the matter, we desire to place before the Convention our opinion, based on some experience in the work of the Society, in whose Board of Direction we have all had the honor to serve.

Amendment No. 1.—This amendment has received the sanction of nine of the twelve Past-Presidents now living, and we believe its adoption will have an important and beneficial bearing on the future administration of the Society, for the following reasons:

First.—The Board, as at present constituted, is unwieldy, and, in one instance at least, in order to overcome this, it was necessary to elect Directors for the purpose of performing a specific act. This was in what was probably the most important action the Society has ever taken, and was necessary, under existing conditions, owing to the impossibility of securing an attendance of two-thirds of all members of the Board at a meeting, otherwise the Society would have been unable to purchase the lots for the New House, to sell the Twenty-third Street house, or to raise the money necessary for the building by placing a mortgage. It does not seem necessary to point out that this condition may occur at any time in the future.

Second.—The number of members composing the Board of Direction is now fluctuating. Since January, 1892 (five and one-half years), when the Past-Presidents were added to the Board, this number has changed eleven times, as follows: 37, 36, 35, 36, 37, 38, 39, 38, 39, 38 37.

Third.—As the Constitution now stands, a President elected for one year must continue to be a Director, and accept for life responsibility as such, even if he does not so desire, the only alternative being resignation from membership in the Society.

Fourth.—We further desire to place on record our opinion that the influence of the Past-Presidents acting as Honorary Councilors will be as much felt under the terms of this amendment as it is under the present Constitution.

Amendment No. 2.—That part of this amendment creating a Board of Direction as distinct from the Trustees of the Society we do not approve for the reasons already given. There is, however, another point to which attention should be called. The amendment proposes that the Secretary shall no longer be a member of the Board of Direction,

Discussion on Constitutional Amendments (continued).

and of this provision we desire to express our disapproval, and to state the reasons governing this opinion.

First.—The duties of the Secretary are defined clearly in the Constitution. He is the executive officer of the Society; must attend all meetings of the Society and of the Board; must collect all money due; carefully scrutinize all expenditures; personally certify to the accuracy of all bills and vouchers; countersign all checks drawn by the Treasurer; conduct the correspondence of the Society; take entire charge of the Society House and contents; supervise the work of all employees, etc. He must also be capable of editing the publications, and must represent the Society and the Board on many occasions, notably in receiving visitors, etc. It is submitted that the above requirements do not indicate that the Secretary should be the only officer of the Society not a Director or a Trustee, and have no voice in the management of the organization.

Second.—The other members of the Board are busy men; two-thirds of them are non-resident, and the position of Secretary should be something more than that of a head clerk, and in order to represent the Board (which meets, at most, twelve times a year) he should be a member of it.

Third.—The proposition is a radical departure from the policy of the Society since its beginning, and we fail to see any reason for its inauguration at this time, when the results of the present system of management, as evidenced by the progress of the Society during the past three years, are unquestioned.

Jos. M. Knap.	S. Whinery.
John Thomson.	Robt. Cartwright.
Thomas Curtis Clarke.	Charles Sooysmith.
Charles Macdonald.	Geo. H. Browne.
J. James R. Croes.	J. F. Wallace.
Horace See.	T. Guilford Smith.
John G. Van Horne.	Robert Van Buren.
Edward P. North.	Thos. W. Symons.
A. Fteley.	G. H. Benzenberg.
Stevenson Towle.	Rudolph Hering.
Clemens Herschel.	James Owen.
Geo. A. Just.	G. Bouscaren.
Walter Katté.	J. T. Fanning.
Jos. P. Davis.	Aug. Mordecai.
John F. Ward.	Chas. Hermany.
Geo. W. McNulty.	O. H. Landreth.
F. Collingwood.	Albert B. Hill.
G. Leverich.	James D. Schuyler.
L. L. Buck.	C. C. Schneider.
O. F. Nichols.	C. C. Martin.
Bernard R. Green.	Thomas Fitch Rowland.
Alfred P. Boller.	Robt. B. Stanton.
G. S. Greene, Jr.	

Mr. Seaman.—Mr. President, I have been keeping tab of the names, and it may be of interest to the members to know that among those forty-five Directors there are three Past-Treasurers of the Society; there are three Past-Secretaries of the Society, and there are nine Past-Vice-Presidents of the Society. I thought that might be of interest to the members.

General CRAIGHILL.—Mr. President, I suppose that we are to have a discussion of this matter, and it is a very serious one. It is one, of course, that the Past-Presidents touch with great delicacy and reluctance, but at the same time I think we should know before this discussion is entered upon, what course it is going to take. Here we have three amendments before us, and, so far as I am concerned, as I propose to say something on the subject, I would like to know in what direction the discussion is to be. I will give notice of the fact now, that I propose to submit two or three, perhaps four, amendments to the first amendment that is before us. It seems to me, Mr. President, if I may be permitted to make a suggestion in the beginning, it would be well that all amendments that are to be proposed should be read, so that the whole subject may be before the Society before the discussion begins.

The PRESIDENT.—I was going to say, sir, that the matter is now entirely before the Society, and it will itself properly direct the course of discussion and business, and the introduction of amendments as you suggest is a part of that, and, I think, in order.

General CRAIGHILL.—I would like to say, before proceeding further—I hope to be excused for taking so much of the attention of the Society—that I have several amendments to offer, and I have no doubt there will be others, but, before doing that, my own belief is that this subject is going to excite a good deal of feeling in the Society, and I will premise what I wish to say in this way. That I am a Past-President; I have been greatly honored by the Society, having been made not only its President, but also an Honorary Member, which is an honor I esteem very highly, but I desire it to be understood that whatever shall come from my lips to-day will be spoken—putting all those things aside—simply as a member of this Society, and with the most urgent wish that we may have harmony and good feeling, and that not one word shall be uttered to-day to disturb that harmony and good feeling. My idea is this, Mr. President, that as the emergency—if I may so call it—which brought up this first amendment, the first amendment leading to the second and the third—that if that whole subject could be dismissed from discussion, I should be glad to see it done. And with that object, I am going to ask for information as to what would be the effect upon the situation if I should move or somebody else should move to lay the whole subject on the table?

The PRESIDENT.—My attention has been called to this matter, and I have taken occasion to form as good an opinion as I could in regard to it. I am heartily in sympathy with what General Craighill has said. It does not strike me that the amendments are matters of emergency. What has occurred may not occur again for a great many years. But the Constitution says:

"Said amendments shall be in order for discussion at the Business Meeting during such Annual Convention, and may be amended in

Discussion on Constitutional Amendments (continued).

any manner pertinent to the original amendments by a majority vote of the Business Meeting during the Annual Convention, and, if so amended, shall be voted upon by letter ballot in form as amended by said Business Meeting; if not so amended, they shall be voted by letter ballot as submitted."

If the motion to lay on the table is made, I should put it and announce the result, but I do not think it would prevent the transmission of the ballot to the Society. It would not stop proceedings under the text of the Constitution: "If not so amended, they shall be voted upon by letter ballot as submitted."

Mr. RAMSEY.—That being the case then, Mr. Chairman, I think we should proceed to a full discussion of the proposed amendments, so that when we come to a letter ballot, as we ultimately will, on one or the other of those amendments, members at a distance will be fully posted as to the requirements at the headquarters of the Society —as to the general situation there.

EDWARD P. NORTH, M. Am. Soc. C. E.—As there is no motion before the meeting, that we may proceed in order, I beg leave to move that the first amendment to Article V, which is signed by a majority of the Past-Presidents, be adopted.

D. E. MCCOMB, M. Am. Soc. C. E.—I second the motion.

J. N. CHESTER, Assoc. M. Am. Soc. C. E.—I wish to correct an impression that I see going out—I had that impression myself—that because certain signatures appear to this first amendment as read, those signatures all being the signatures of Past-Presidents, that those persons are in favor of that. I do not believe there is one of them who is in favor of it, and they simply signed it because they were asked to and not because they wanted the amendment to pass. Now, in talking to the different members of the Society, I find that the opinion prevails that because these men have signed this, they wanted this amendment passed. Such is not the case. I have not been able to find a single one who wanted that amendment made.

Mr. KNAP.—I wish to say that the aspersion cast upon the signers of this amendment is unwarranted. I do not think that eight of our Past-Presidents would sign a paper they did not wish to sign, simply to please their friends. I think they signed it with a full knowledge of what they were signing.

P. ALEX. PETERSON, M. Am. Soc. C. E.—I would just say that I have spoken to some of the Past-Presidents who have signed this paper, and I think it is a matter of considerable indifference to them whether the motion be passed or not. I think that they would prefer to leave it as it was originally, and their reason for signing it was because a difficulty arose as to selling our present building that may never arise again. I think it is a mistake to put our best men on a Board and not allow them to vote. I introduced the original resolution putting Past-Presidents on the Board of Direction, and putting

them on the Nominating Committee. I think if we are to put our best men on a Board, merely letting them go there and take part in the discussions, being afraid to give them a vote, it is a very extraordinary proceeding. I think we ought to leave the matter just as it is, and I think that our Past-Presidents are quite willing—those who did sign the amendment—to remain on the Board and to perform the duties that they are to perform. We wish to have a conservative party here. We do not wish to be carried away hither and thither every time, and to be changing our Constitution every two or three years, and I believe that when we think this matter over carefully, the majority of us, if not all of us, will be in favor of leaving our Past-Presidents just where they are and giving them authority to vote as well as to discuss.

D. J. Whittemore, Past-President Am. Soc. C. E.—I had made up my mind not to speak on this question at all. I know that I am placed in a delicate position, and I ought to be very careful what I say. Yet, as one of the signers of this proposed amendment No. 1, I wish to say that when it came to me I thought I gave it due consideration; that there were members of this Society who wished to take from the Past-Presidents something that had been conferred upon them before, and believing there was a respectable number of members that desired to abrogate what had been conferred upon the Past-Presidents, I thought it my duty to sign it. If the Society wishes to have amendment No. 1 carried, I shall be satisfied to stand in the background with the badge of Past-President and nothing more. I wish to say that this is a matter for the members themselves to settle. I feel very delicate about speaking upon the subject in any manner whatever.

Mr. Oberlin Smith.—It so happened that being very busy I did not see these amendments when first printed. I had my attention called to them only last night. The moment I read them, it struck me that neither of them ought to be passed by this Society; that we ought either to let everything go just as it is or straighten the matter out so as not to give effect to either of those amendments.

The exact meaning of the first is to turn out all our Past-Presidents from the Board of Direction. The meaning of the other is to turn out our Secretary. Now, we cannot afford to do either. Taking the last matter first, we have a very efficient Secretary. We expect to have one, we cannot get along without one, and he is more intimately connected with the Society's business than any other one man, or perhaps any other ten men in the whole Society, and to leave him out of the Board of Direction would be ridiculous. Therefore, I should absolutely oppose the second amendment. The Secretary belongs there and should be there.

On the other hand, our Past-Presidents are supposed to be the

Discussion on Constitutional Amendments (continued).

flower of the whole Society. They are supposed to be selected by all the other members as men most eminent in their profession, best qualified to represent the Society at home and abroad. It is a very pretty and graceful custom, instead of leaving them in only a year and then turning them out in the cold, to take them into the Board, as practiced by this and other Societies, making the Past-Presidents honorary councilors, or councilors of some sort, forming a part of the Board. Why a man who is thus eminent, who thus is an honor to the Society, should go out any more than an army or navy officer should go out from government service because his immediate duties are done, I don't know. Why his office should not be for life, I cannot imagine. The fact that some of these Past-Presidents have signed a recommendation of this amendment is nothing. These men are modest men, as well as representative men of the Society. You can hardly expect them to blow their own trumpets, and when approached with an amendment of this kind, any modest man would naturally say, "Why, it does not make any difference to me; if the other Members wish to leave me out, I am perfectly willing."

These gentlemen want to do what the Society wants them to do. If the Society wants them to retire, or partially retire, from the council, they are perfectly willing to, as I understand. The only reason I know, with my limited knowledge of the subject, why we want to turn these men out after having them in a good many years, is because we may not be able to deal in real estate as rapidly and conveniently as we otherwise would. I don't know whether the Society intends to start a real estate office, a conveyancer's shop in New York, but here is an emergency which has come up once and is all happily settled, being only a matter of a little more trouble in getting the men together. We hope it will be a great many years before we need to throw away this new house and get another one. Of course, if we should outgrow it, the glory of having a still bigger house would prompt us to make special efforts to get these men together if we had to send special trains for them. So I don't think this matter of transferring real estate is worth talking about. It probably will not occur again in the lifetime of these Past-Presidents we are now discussing.

The only question that remains is, whether we do or do not want these representative men of our Society in the council. If they had never been in, the question would not be of so much importance; but, having them in, to turn them out now is beneath the dignity of this Society. It would not look well in this country, it would not look well abroad. It might in some cases make us a laughing stock. If there are any legal difficulties, if there are any questions that must come up that cannot possibly be settled without collecting these men from all over the land, it can be arranged as it is arranged in some of the other Societies. In one of our large sister societies with which I am con-

nected, the Past-Presidents are all made honorary councilors for life, full members of the council, to deliberate and vote on all questions except those affecting the legal status of the Society and its members. Here is a copy of the Constitution of the American Society of Mechanical Engineers:

(Reading) "Article XX.—The affairs of the Society shall be managed by a council consisting of a President, six Vice-Presidents, nine Managers, and a Treasurer, who shall also be the Trustees of the Society. All Past (ex) Presidents of the Society, while they retain their membership therein, shall be known as Honorary Councilors, and shall be entitled to receive notices of all meetings of the Council, and may take part in any of its deliberations; they shall be entitled to vote upon all questions except such as affect the legal rights or obligations of the Society or its members."

That provision in the Constitution of that Society has been in force for several years; I do not remember how many, perhaps eight or ten. I think it was probably copied in a measure from this Society, and perhaps from the British Institution also and other societies. So far it has worked very well, and no doubt it will continue in that way. They got over any legal trouble there might be in regard to transferring their property when they bought their house in New York, in that very way. So far as I am concerned, I would not mind a provision of that kind if it is necessary—if the legal lights of this Society think it is necessary to put a clause of that kind in as an amendment to one of these amendments, or as a new amendment—that would be all right, although, personally, I should not think it was necessary to do anything. If my personal wishes were consulted I would drop the whole thing, but for heaven's sake, don't let us turn these honorable men out in the face of the whole world and put them out of doors.

Mr. Seaman.—I am exceedingly sorry to see the personal element creep into this discussion. There is no one who thinks more, there are no members who think more, of our Past-Presidents than the people who elected them, and they will always continue to do so. We hold a great many of them in high esteem and love and even veneration. It is not the purpose to turn Past-Presidents out of the Board of Direction; it is an effort and an honest effort—and if these Past-Presidents so understood it, they would endorse it—it is an honest effort on the part of the Society to lead an honest career. We have within the last year found it necessary to make sales and purchases of real estate. We do not propose to go into the business as it has been here expressed, but when it becomes necessary in order to accomplish that purpose to put ourselves on record in an unenviable light, we fail to accomplish the purpose for which we set out. If to accomplish that purpose two members or three members resign from the Board of Direction with the understanding that such resignation shall be for two or three days, and in the meanwhile two more members are elected and they resign and in time are replaced by the first, and those resig-

Discussion on Constitutional Amendments (continued).

natoins are not in good faith. While a lawyer might endorse them, I doubt very much whether the Court of Appeals will if it is ever brought there.

The purpose of this amendment, as I understand it, is to increase the efficiency of the Board. It is not in any way to reflect upon those whom we have honored and whom we propose to honor and to continue to honor in the future. It has already placed us in a position in which we have been unable to do business. In the past it was necessary that our Past-Presidents should be members of the Board of Direction to maintain a conservative element, because every year our Board of Direction was renewed from top to bottom. Since then the arrangement is that we elect our Directors for every three years, the necessity for such conditions has ceased to exist, and new conditions have arisen which make it very cumbersome to the Society. I merely rose to say I was sorry that the proposed action should be placed in the light of a reflection upon those whom we have honored and whom we always hope to honor.

Mr. Moore.—Mr. Chairman, as one who has voted for the amendment No. 3, I would suggest that it will simplify the discussion if amendment No. 3 be dismissed from consideration, for the time at least, and consideration concentrated upon amendment No. 2 which is substantially the same, with some verbal changes which do not affect the meaning, so that practically there are two amendments before the Society, amendment No. 1 and amendment No. 2, and these two amendments bring up two distinct subjects. One of them affects the status of the Past-Presidents—leaves them entirely out of the Board of Direction or with no power to vote—leaves them out as Trustees and with no power to vote in the Board. The other leaves them out as Trustees in matters affecting the title to the property, but leaves them in the Board with full power to vote as well as to give their counsel. Now, we all recognize the practical difficulty which has been mentioned, which did arise in the transfer of property, and although it may never arise again, yet it is possibly worth while to provide for it. I said "possibly," and I think it is fully provided for in the second amendment. They are simply no longer Trustees of the property, and their vote is not needed in the transfer of property. The title to property could as well be left in the hands of one Trustee, but to simplify that matter it is provided that they shall not be Trustees, and I think that fully meets the whole difficulty arising under that head. I think that no one, even the proposers of amendment No. 1, really desire that the Past-Presidents should be left out of the Board of Direction altogether; so that I take it, so far as that subject is concerned, the provision of amendment No. 2 would perhaps meet the views of those who proposed the original amendment, and if anything is to be done upon the subject, I should say that it would be fully

met by the provision of amendment No. 2 so far as it affects that subject.

There is also another matter which is covered by amendment No. 2 which, however, a change of a single word would entirely modify, and that is to leave the Secretary out of the Board as a member of the Board. You all know that until a few years ago the Secretary was elected by the Society at large. A few years ago, owing to causes which it is not necessary to go into, it was thought best that that practice should be discontinued, and the Secretary was made an appointee of the Board of Direction. Now, when that was changed, logically and in accordance with universal practice you may say, in such cases, an appointee of the Board is not logically a member of the Board. He is appointed and removed by the Board, and I think that if the movers of the original amendment had recognized the inconsistency, the change would have been made at that time. This part of the amendment is in accordance, so far as I know, with universal practice, where the Secretary is an appointee and removable by the Board which he serves. It is so in the Institution of Civil Engineers —it is so in several similar bodies that I know of, and I think that it is, as I say, practically in accordance with universal experience under those conditions. It seems to me that amendment No. 2 on the whole meets, as I say, in regard to the first subject, the real wishes and purposes of the movers of amendment No. 1. And in regard to the other subject, it certainly conforms to the logic of the situation and to the universal practice in such conditions in regard to the appointees of the Board. I should therefore certainly vote against amendment No. 1, and I think the friends of No. 1 should vote for No. 2.

Mr. Oberlin Smith.—I have but a word to say. It seems to me that if our Secretary is good enough to do our business—we all have confidence in him to elect him either directly or through the Board—he is good enough to be a member of the Board, and the whole thing could be perhaps brought to a proper head by adding the words in amendment No. 2, "and the Secretary," after saying that the President, Vice-Presidents, Directors, Treasurer, etc., shall be members of the Board—to add the word "Secretary" to the list, and we would have him in there as he ought to be, and we would still have our Past-Presidents where they ought to be.

The President.—Is that a motion, sir?

Mr. Smith.—I made that as a suggestion.

The President.—Is it an amendment?

Mr. Smith.—I will offer that as an amendment, that the words "and Secretary" be added to the list of officers.

The President.—On a question of so much importance I would like to have everything of that sort written out. As I understand now there is simply one motion before the house made by Mr. North, for

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the adoption of amendment No. 1, and what has been going on is the discussion of Mr. North's motion. I watched, Mr. Moore, but I did not understand you to move the adoption of No. 2.

Mr. MOORE.—I have not moved the adoption of No. 2. I supposed the matter would be settled by voting for No. 1, and if No. 1 should be voted down and the question should come on No. 2, then the amendment made by Mr. Smith would be germane and in order.

Mr. OBERLIN SMITH.—I will let go what I said merely for suggestion. I beg pardon for being out of order. I lost sight of the fact that we had another motion before the house. After the other is disposed of, I will offer that as an amendment.

General CRAIGHILL.—As I understand the situation, the subject before the Society at this time is the adoption or rejection of amendment No. 1 as printed. I wish to give notice that I have two or three amendments to offer to that amendment, and I honestly believe that if they are heard by this Society and carefully considered it would end the whole subject. This conforms with the idea which I expressed in the beginning, that before we enter on a discussion we have the amendments read which were prepared, in order that we may understand the situation thoroughly.

The PRESIDENT.—I recognized Mr. Morison. If he will yield, sir——

Mr. MORISON.—There are one or two things which I want to call the attention of the Society to, and there are some other matters which I wish to speak of, but I will not speak of them now. There seems to be some misapprehension as to the history and the present condition of the Board. Mr. Seaman has mentioned that it was formerly necessary to have the Past-Presidents in the Board of Direction in order to preserve an element of conservatism when the Board changed annually. It was when the Board did change annually, according to my recollection, that the Past-Presidents were not members of the Board. They became members of the Board at the time that the three-year graded Board was formed. It must also be noted that Past-Presidents before that time had certain responsibilities and certain labors to perform, which they did not do as members of the Board but because they were Past-Presidents under certain special provisions of the Constitution. Honorary Members could at that time only be elected by the unanimous vote of the Board of Direction and of all living Past-Presidents. If this amendment No. 1 passes in its present form, it would give the Past-Presidents no powers whatever, except the right to go to meetings of the Board, which other members of the Society do not have. It will place the election of Honorary Members entirely in the hands of an elective Board of Direction without any reference to Past-Presidents. The form of the Constitution is such that it will have that effect. I simply wanted to speak now in order to correct those errors. I shall have something further to say later.

General CRAIGHILL.—With reference to the statement made a little while ago as to the signers of amendment No. 2, as my name will be found attached to it, I wish to say this—there is an old motto which I have read and I suppose a good many others have, that with additional information a wise man may sometimes change his mind, but a fool never. Now, I do not claim to be a very wise man, but I have had additional information on the subject of these two amendments, and I have changed my mind with reference to both and for good reasons, which I will undertake to state if I am permitted by the Society to do so, and I now say emphatically that I do not now approve of either.

I propose, with the consent of the Society, to read certain amendments to the first amendment, which is now before the Society. I propose to insert after the word "Treasurer" the following: "and the five latest Past-Presidents," which will make the amendment, so far as that is concerned, read in this way: "The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Secretary and a Treasurer, and the five latest Past-Presidents.

Another amendment comes in: I am confining myself to No. 1, which, as I understand it, is all that is before the Convention at this time. After the word "Past-Presidents," insert the words, "except the five latest," so that the sentence will read as follows: "All living Past-Presidents who continue to be members shall be entitled to be present at all meetings of the Board of Direction and to discuss all questions coming before the Board and aid the Board by their advice and counsel; but said Past-Presidents, except the five latest, shall not have a right to vote, nor shall their presence be requisite in order to constitute a quorum."

I will read still another amendment, to be inserted at the end, after the word "quorum": "And every Past-President, so long as he remains a member of the Society, shall be entitled to vote by letter for any person proposed for Honorary Membership, unless such Past-President be disqualified by mental or bodily infirmity; and the evidence of such disqualification shall be a written certificate from his attending physician or some officer of the Society."

Those are the points which I wish now to bring before the Society and to make few remarks with reference to them.

The first amendment, which inserts after the word "Treasurer," "and the five latest Past-Presidents" and excludes the others, is in accordance with business principles, with the precedent which is set us by the British Institution of Civil Engineers; and the American Society of Mechanical Engineers, as its president has just informed us, adopted the same rule to a certain extent. But, as I understand the situation, the origin of this first amendment is as follows, and if I am mistaken I wish to be corrected by those who know better. We have lately been disposing of our old house, which was a business

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transaction; and we have lately been purchasing a new one, which was another business transaction. In doing so it was found that under the laws of the State of New York it was difficult, in fact, impossible, to get a sufficient number of the Board of Direction present to act in that respect as trustees of the Society, and I must say emphatically that I disapprove absolutely of the method which was adopted.

Now, Mr. President, I recognize the necessity at this time of reducing the number of the Board of Direction as a business proposition. I think it is too large, and it should be reduced. I think the number of members of the Board of Direction, with all the Past-Presidents in it, is between thirty and forty. I do not recollect those figures exactly. But with the five latest Past-Presidents in the Board it would not be a cumbersome Board; and there are certain advantages in having a certain number of the Past-Presidents of the Society in the Board. I speak now without reference to anybody in particular. I am talking business now entirely, as a member of the Society, without regard at all to the fact that I am a Past-President, which I ignore utterly at this moment. We have a precedent for what I propose, that is to say, the precedent of the British Institution of Civil Engineers, which stands as high in this country and any country for wisdom and long experience as anybody we can mention. It is its rule to have in its Board of Direction four or five of the Past-Presidents. It introduces them into the Board in a manner different from that which I propose; that is to say, its council elects them annually. Now, that brings up a subject which has a bearing upon this. I desire to say that some years ago there existed a certain sectional jealousy in the Society, principally due to the fact that a great many of our members are not familiar with the workings of the Board. They were jealous of the influence of New York, and they were a little jealous of our own Board. Happily, this feeling does not now exist to any great extent. The members of the Board of Direction do not all live in New York, but as a rule the quorum of the Board which does business is mainly composed of New York members. It is one of the necessities of the institution; we must have a headquarters; we must have local members to transact business, or else we won't get through with our business at all. So that the composition of the Board, so far as that is concerned, ought not to be objectionable to any fair-minded man who thinks of the situation seriously. But one advantage which I think will follow from the understanding that the five latest Past-Presidents are members of the Board of Direction for all purposes, is that they are men of standing in the Society who cannot all be Resident Members. A feeling of responsibility would rest upon them if they were elected as members of the Board—it amounts to re-election every year—and they would attend the Board meetings as the Past-Presidents do not now, and certainly would not if they were simply to come there as councilors to the

Board. They are not all in New York, but we might expect that they would attend under a sense of their responsibility, under the peculiar conditions with which they were attached to the Board as selected members. I believe that the influence would be good in the Board, and that it would be good in the Society, and for these reasons I urgently recommend this amendment to amendment No. 1.

Now, with reference to the point that Mr. Morison referred to, and which is covered by one of these amendments. It is known that from time to time we elect Honorary Members, and that the Constitution, as it now exists, requires that they should be elected unanimously by the Board of Direction. It seems to me there is a special propriety in giving to the Past-Presidents of the Society the privilege of voting for Honorary Members, at any rate, and that is one reason why I have prepared the amendment to amendment No. 1, which has been read and permits every Past-President to vote for honorary membership. Let it be understood that when that vote is taken for honorary membership it is not in the Board. It has nothing to do with the business of the Board. It is by letter, each one voting separately. There is no hurry, and there is no reason in the world, to my mind, why the present arrangement should not continue, that all the Past-Presidents should be permitted to vote for Honorary Members of this Society. That is the object of the third amendment which I have proposed.

Coming now to the business of the Society, that is where we need the action of Trustees. As the law of New York is now, I understand that it is necessary for two-thirds of the Trustees——

The Secretary.—There must be an affirmative vote of two-thirds of the Trustees, and this vote must be given at a meeting.

General Craighill.—It is found that it is difficult to transact business, such as the acquisition of property, or the disposition of property, or its management, through the agency of the whole Board, on account of its great numbers. That is another reason why I am willing to see a reduction in the number of Past-Presidents who are members of the Board; at the same time I thought that even that would make a cumbersome trusteeship; therefore, I have a fourth amendment to amendment No. 1, which I propose to submit to the Society. It is the following:

"The Trustees of the Society, for the disposal and acquisition of property under the law, shall be the President of the Society, the local Vice-President, the Secretary, the Treasurer, and the Chairmen of the special standing committees."

Now, those are all men convenient to New York. They are business men. We have the President, the Vice-President, the Secretary, the Treasurer and the Chairmen of the standing committees of the Society, who are all members of the Board, and, in my judgment, they

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would constitute an excellent Board of Trustees, under the direction of the whole Board, for the performance of this special duty.

I think I have nothing more to say on the subject, Mr. President, but I should be exceedingly gratified if these amendments were acceptable to the Society.

Mr. KNAP.—I am very sorry that the last speaker made the fourth amendment. I was about to rise to endorse heartily the three amendments, for I think that would be a solution of the whole difficulty and the friction and trouble we have had.

General CRAIGHILL.—If that is the case, I withdraw the fourth amendment.

Mr. KNAP.—It might not make it legal in accordance with the laws of New York State to have a Board of Direction and also a Trusteeship, a portion of the Board making up a Board of Trustees for the transaction of business——

General CRAIGHILL.—I withdraw the fourth amendment.

Mr. KNAP.—That being withdrawn, I simply wish to state that I heartily second and endorse these three amendments given by General Craighill. I think that will be a solution of the whole difficulty, and I am very certain it will meet with the very general approval of the Society.

Mr. METCALF.—Mr. President, I did not intend to enter into this discussion any more than any of the other Past-Presidents did, but I think I state the sense of all when I say that we simply stand ready to do whatever this Society shall decide is best to be done.

There are one or two little matters that came up to-day, one particularly, that need explanation. Our friend from Pittsburg said in the beginning that the signers of this first amendment did not necessarily mean that they approved it by signing it. He was afterwards reprimanded for casting aspersions on the signers of the amendment. I would like just to explain to the Society what did happen, so far as I am concerned. I, of course, know the difficulties about this transfer of the property, and some months ago I received a letter from a member of the Society, and an honored member, asking me if I would be willing to sign for the purpose of putting it forth—an amendment to the Constitution organizing the Board something after the style of the Board of Mechanical Engineers, which was spoken of this morning. Seeing at once that this was an effort—probably a right one—to change the status of the Past-Presidents, I replied, "Yes, I would." After that, this amendment No. 1, nearly as it is now, was sent to me to sign, and I returned it modified in accordance with the first suggestion. Then word came back that the amended form would not be legal in New York, and, therefore, the form that is now sent out was returned with the request that I sign it. There was no explanation of why the Mechanical Engineers could do a certain thing legally, and the Civil Engineers could

not. But that can be passed over. The reason that I signed it was simply because I was asked to in order to get it before the Society, and I presume that is the reason why every Past-President whose name is on there signed it—because we could not refuse to sign anything of the kind, and it does not mean and could not mean that we approved it. Now, if this meeting or the Society want to send that amendment out, all I have to say is—and I beg the members to do that—cut out all reference to the Past-Presidents, or, if the meeting prefers, send out that amendment amended as General Craighill has suggested, which seems to me admirable. I hope, however, that he will withdraw the second part of his amendment, and leave the last five Past-Presidents on the Board as active members of the Board and make no reference whatever to the status of the Past-Presidents after their five years of service, because even after that time I do not think the Past-Presidents want to be made members of a gossip committee in the Board, for that is all it would be. I think I voice the sentiments of all the Past-Presidents in saying that they would have no feeling whatever if they are eliminated from the Board. All would be just as much interested in the Society and would work just as heartily for it as if left as they are. But that amendment putting them in the position proposed is simply an insult and an absurdity. If you wipe that out and wipe out the Past-Presidents, well and good. I will vote for it willingly. If not, I would approve of General Craighill's amendment, which seems to be good. I hope that he will cut out that second one. That will put the last five Past-Presidents in the Board, leaving each President elected to understand that he has to give six years of his service to the Society. It strikes me as a very good amendment. It gives you a Board of a fixed number, omitting all reference to the President or Past-Presidents as members of the Board; and then the provision made of allowing Past-Presidents to vote for Honorary Members—I see no objection to that. That, of course, will have to rest with the members. I am not making any plea for any honors or rights for the Past-Presidents.

I have only one more word to say, and I will not say it in the way of throwing mud; but statements are made sometimes that need explanation. A gentleman has told you of the troubles found by the Board in getting the necessary number together to vote for these transfers of property, and I am sorry that the gentleman in his remarks gave the impression to this meeting and to the Society at large, that the Board resorted to some sort of scheming to carry out that legal process necessary to acquire the new property and dispose of the old. Now, the fact is, that when the suggestion was made that those members of the Board should resign and others be elected, it took the members of that Board about three hours to convince the Past-Presidents that they were not scheming. The Past-Presidents made all the

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trouble that time. I heard of one who told another that he wished he had him outside so he could thrash him. But as a matter of fact, there was no question of scheming, the matter was explained clearly and legally, and it was demonstrated that these gentlemen could resign from the Board. We all know the Board had the right to fill vacancies. We did it. The action was perfectly open and above board, perfectly honorable and perfectly legal.

George A. Just, M. Am. Soc. C. E.—I think that the Society here this morning has made very rapid progress toward the solution of this problem by the close study of the question that General Craighill has evidently given it, and by the suggestion of Mr. Metcalf, and I think, perhaps, I might make a motion now which would probably have to be in the form of an amendment, and also an original motion, which would cover the entire ground and leave the matter exactly as the Society now wants it; that is to say, the amendment would then read with the amendments of General Craighill, wiping out the last section —that has all been thrown out for certain legal reasons—taking out the section to which Mr. Metcalf had an objection, and we do not need the final paragraph, which tries to limit the Past-Presidents in some way, and I would, therefore, move——

The President.—One minute, please. Then the position would be this, that General Craighill has moved an amendment to amendment No. 1. and you are offering an amendment to General Craighill's amendment.

Mr. Just.—Exactly.

The President—Then, if that is acceptable——

Mr. Morison.—As a method of expediting business, if General Craighill's amendments have not been seconded, I would second them now, and move that a vote be taken on them successively, first on one and then on another.

John Thomson, Treas. Am. Soc. C. E.—Major Knap seconded the amendments of General Craighill.

Mr. Just.—If I may crave pardon of the assemblage, I yielded the floor to Mr. Morison, and I do not think that Mr. Morison should have put in a motion ahead of mine when I had the floor.

Joseph P. Frizell, M. Am. Soc. C. E.—I think you cannot offer an amendment to an amendment to an amendment.

Mr. Just.—This is an amendment to an amendment. We have only reached the point of an amendment to an amendment.

The President.—That is right, I think, sir.

Mr. Just.—Now, Mr. President, the reason I asked that I might make this amendment is that I think the views which have been here expressed will be combined in this motion, and any motion which Mr. Morison wanted to make would probably not become necessary. I should like to read the amendment as it will read as I propose to

amend it: "The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Secretary, and a Treasurer"—there we get the amendment of General Craighill—"and the five latest Past-Presidents, who shall constitute the Board of Direction in which the government of the Society shall be vested, and who shall be the Trustees provided for by the laws under which the Society is organized." And cross off the final paragraph, which limits the powers of Past-Presidents. We have simply the five Past-Presidents on the Board without limitation, and I think it combines the views which have been expressed in the discussion here.

Mr. North.—I would like to second the amendment and accept it so far as it relates to my motion.

The President.—Mr. Just, will you have that transmitted up here?

General Craighill.—I suppose it is for me to say whether I accept the amendment of Mr. Just.

The President.—Yes, sir.

General Craighill.—I am perfectly willing to do so if it be the wish of the Society to exclude from voting for Honorary Membership all the Past-Presidents except five. That would be the effect of this amendment, as I understand it.

Mr. Just.—No, no, not at all. I do not intend such a thing. It will have no limitation whatever on the voting power.

General Craighill.—Under the Constitution, the Honorary Members are elected by the Board of Direction, and if there are only five Past-Presidents on the Board, the others could not vote.

Mr. Just.—That is embraced by your amendment No. 3.

General Craighill.—It embraces amendment No. 3? Oh, well, I accept the amendment. It was not so read, Mr. Just.

Mr. Just.—That was my error.

General Craighill.—I accept the amendment, with the understanding that my third amendment is to be a part of the——

Mr. Thomson.—Will General Craighill please read his amendment again?

General Craighill.—The object of this third amendment is just as I have stated to Mr. Just. The object that I have is to make the five latest Past-Presidents members of the Board of Direction, and, of course, in that capacity they would be eligible, under the Constitution, to vote for Honorary Members; but the other Past-Presidents—I believe there will be seven others, I am not sure—unless this amendment passes, they would have no right, not being members of the Board of Direction, to vote for a person proposed as an Honorary Member.

Mr. Thomson.—That would still require a unanimous vote of all the Past-Presidents.

General Craighill.—Yes, of all the Past-Presidents. That is my

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object. It is a mere compliment. It does not interfere with business in any way whatever.

Mr. THOMSON.—In the event of illness or absence——

General CRAIGHILL.—That is provided for.

Mr. THOMSON.—I did not hear that.

General CRAIGHILL.—I will read it again: "And every Past-President"—not only the five, but all the others—"so long as he remains a member of the Society, shall be entitled to vote by letter"—not in the Board, but by letter. It does not interfere with the business of the Board in any way.

Mr. THOMSON.—That is the present method.

General CRAIGHILL.—That is the present method. (Reading) "by letter for any person proposed for honorary membership, unless such Past-President"—we know we have had such cases—"unless such Past-President be disqualified by mental or bodily infirmity"—that is the very case we have had, and this is intended to cover it—"And the evidence of such disqualification shall be a written certificate from his attending physician or some officer of the Society." It seems to me it is perfectly guarded, and it ought to be satisfactory to the Past-Presidents. I do not see that any member of the Society could have the slightest objection to it.

Mr. THOMSON.—I think, sir, that removes the difficulty.

General CRAIGHILL.—As I understand it, the amendment that Mr. Just offers would include this.

Mr. JUST.—It would include this.

General CRAIGHILL.—All right, then.

The PRESIDENT.—Then you accept Mr. Just's amendment (addressing General Craighill)?

General CRAIGHILL.—I accept it.

The PRESIDENT.—Then, Mr. North, you accepted General Craighill's amendment?

Mr. NORTH.—Yes, sir.

Mr. C. FRANK ALLEN.—It has occurred to me it might serve the same purpose if, instead of the qualification as to a physician's certificate, a clause could be inserted that the failure of such Past-Presidents to vote shall not vitiate the ballot; that the Past-Presidents should have the right to vote, but should not be compelled to. It seems to me that possibly it would be more graceful to put it in that shape, rather than call attention to the specific case.

General CRAIGHILL.—I have no objection whatever to that.

Mr. MOORE.—I would suggest if we are to vote on amendment No. 1 as amended and reamended, it ought to be carefully digested, so that we may know exactly on what we are voting. I think no member now does, with the various amendments and reamendments.

The PRESIDENT.—It will be read, sir.

Mr. MOORE.—And may I be allowed to say that it seems to me, as I urged before, that every purpose which this first amendment is intended to accomplish will be accomplished by amendment No. 2.

General CRAIGHILL.—With much regret, I must call the gentleman to order. Amendment No. 2 is not under consideration at this time.

Mr. MOORE.—I am discussing the subject before the house, if I understand it, Mr. Chairman.

The PRESIDENT.—The understanding I have of the subject is this, that we are now passing these amendments to a ballot of the Society; that is what the action of this meeting amounts to. I suppose that it would be the order of business to pass this amendment No. 1. If No. 1 has a majority, that is the only one that would go to the Society, as I understand it.

The SECRETARY.—No, sir. All would have to go.

The PRESIDENT.—Then, it seems to me, Mr. Moore, the proper way would be to get through with this No. 1 amendment and then come to No. 2, and pass it through the same process, both going to a ballot before the Society.

Mr. O'ROURKE.—In listening to this discussion, one fact seems to be accepted by everybody, and that is, that Past-Presidents will take anything you give them. Now, I do not doubt that there are some things they would take, but I consider that if the presence of Past-Presidents on this Board is desired, that there ought to be something in this amendment which will insure the fact that they want to go in. Now, we choose by this means a President who shall be a member of the Board of Direction for five years after his term of office has closed. Anybody who has been the President of a society like this and gone through all the labors of it might not feel inclined at the close of his term to take up the duties of a Director. I think that it will not vitiate in any way the effect of having five Past-Presidents in this Board if instead of saying that the last five Past-Presidents should be members, that we should say that the last five Past-Presidents who will consent to act as such should be members.

General CRAIGHILL.—May I be permitted to say a word? In framing this amendment I simply followed the precedent which our Society has already established. The Nominating Committee is composed of certain persons elected by the Society, and the Constitution says that *ex officio* the five latest Past-Presidents are members of the Nominating Committee. Following that precedent and having it in mind, I suggested that the Board of Direction should include the five latest Past-Presidents, having been all recognized by the Society for the performance of a certain duty, and when a duty is imposed upon a man with its responsibility, if he is a true man, he responds.

There is another reason which I may be permitted to state, which is this: That they, having been recently Presidents of the Society, are

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more familiar with the workings of the Society under its latest Constitution and amendments than any of the other Past-Presidents. That is another reason why I mentioned them, and it was not done without careful consideration. They have lately been Presidents of the Society and have been with the Board of Direction, and they are familiar with the Constitution in its latest form, and with its workings, its advantages and its defects, and from that point of view, also, I am convinced that the amendment I propose is the best solution of the subject.

Mr. O'Rourke.—I believe I merely gave way to General Craighill for a moment. I think that what General Craighill says is true. If we could get the last five Past-Presidents to act, it is what we ought to do.

General Craighill.—We know that they will, because they go to the meetings of the Nominating Committee, and they will go to the Board meetings whenever it is necessary. Ask us! I will! Here is Mr. Morison, ask him! Ask Mr. Metcalf!

Mr. O'Rourke.—If it related to those past five I would not say a word. I have been president of my alumni society, and one of the unwritten laws of that society is, that at the close of the president's term of office, which is the same as this, he shall go on the Executive Committee for one year. Now, that is one of the conditions that makes it difficult to get a president for that alumni society, because busy men do not want to tie themselves up for the time that is necessary to attend to duties that are lower down, so to speak, than the honors they have been heretofore enjoying. I should say that it will, perhaps, make it easier for some who may become Presidents to accept that office, if they can, at the end of the term, cut off the succeeding five years.

Mr. Oberlin Smith.—I think we are losing sight of the things brought up here first, and which seem to be pretty popular among this audience. We want to do proper honor to our Past-Presidents; and although it may please these gentlemen to limit them to five years, it ought not to please the Society. We are not trying to please the Past-Presidents. We are trying to keep up the dignity of our Society and to do honor to our best men. In passing this amendment you simply keep in five of those men and turn the others down. They are simply a gossip committee, as has been said here, to give a little feeble advice. I say this Society ought to keep these men in position for life—in a proper position, subject to such conditions as are necessary.

(Question called for.)

Mr. Morison.—Before this question is voted on, I want to bring up a little different matter. I am afraid we are going to have an amendment which will be a little botched.

The PRESIDENT.—The amendment is ready now, sir.

Mr. MORISON.—It seems to me—Well, if you will read it——

(Question called for.)

The PRESIDENT.—This is Mr. North's motion—to pass amendment No. 1 to a ballot. Amendment No. 1 was amended by General Craighill. General Craighill's amendment was amended by Mr. Just. Then General Craighill accepted Mr. Just's amendment, and Mr. North accepted both amendments.

The SECRETARY.—As amended, then, by Mr. Just, the amendment reads as follows:

"1. The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors. a Secretary, a Treasurer, and the five latest Past-Presidents, who shall constitute the Board of Direction in which the government of the Society shall be vested, and who shall be the Trustees, as provided for by the laws under which the Society is organized. Every Past-President, so long as he remains a member of the Society, shall be entitled to vote by letter for any person proposed for Honorary Membership, unless said Past-President be disqualified by mental or bodily infirmity; and the evidence of such disqualification shall be a written certificate from his attending physician or some officer of the Society."

(Calls of "Question.")

Mr. MORISON.—Is that last sentence in the proper place? It ought to be in Section 1 of Article III. I believe that is the place where that belongs, and I believe when we are amending a proposed amendment to the Constitution, that it includes the right to distribute that amendment, and that we can put the last sentence in Section 1 of Article III, which is the proper place for it.

General CRAIGHILL.—As I understand the situation of the amendment I offered—and I did it after careful consideration of the Constitution from all points—what we are trying to do is in accordance with the provision of the Constitution which I read, in order that there may be no misunderstanding:

"Amendments presented to the Secretary not less than sixty days previous to the date of the Annual Convention, shall be sent by letter to the several Corporate Members of the Society at least twenty-five days previous to the Annual Convention."

That was provided for—that is to say, the three amendments comply with that provision of the Constitution:

"Said amendments shall be in order for discussion at the business meeting during such Annual Convention."

That is what we are about at this time—discussing these amendments in accordance with the Constitution. "And these amendments may be amended in any manner pertinent to the original amendments"—nothing else. We have nothing to do with any other part of the Constitution. What we are engaged upon is the amendment of these amendments which have been submitted to this Convention in a constitutional way. As to any discussion of any other part of the

Discussion on Constitutional Amendments (continued).

Constitution, we haven't anything to do with it, it seems to me, at this time. The Constitution does not provide for any discussion at this time except on this particular business which is before us, and the things that are touched by this amendment to the Constitution, which is now under consideration, are the composition of the Board of Direction and the relation to that Board of the Past-Presidents. My amendments are entirely confined to those subjects and they are germane to them. I know perfectly well what my friend is trying to do. He is trying to keep us in good shape, but I am trying to do the same thing, and I think it cannot be done in any other way except the way in which I am proposing. His method is impracticable at this time. It might come up later and then I would work with him, but at this time I am obliged to say that I think his method is not practicable.

(Calls of "Question.")

Mr. Brinckerhoff.—I would ask for information, whether by "the five latest Vice-Presidents" you mean the five latest living Vice-Presidents, or do you mean those whose terms of office have expired within five years? Of course, I do not suppose anybody imagines we are going to have any dead Vice-Presidents in the Board. You see, it does make a difference whether we limit it to those whose terms of office have expired more than five years ago, or to the five latest living Vice-Presidents. I simply wish to ask what that means.

The President.—The five latest "Past-Presidents"—not "Vice-Presidents."

Mr. Morison.—I am not quite willing to accept General Craighill's interpretation of the ability of this Convention. I think that we have the right in making an amendment to put that amendment where it belongs. This subject is before the Society. There are certain duties which Past-Presidents have. It is proposed to curtail those duties. That is all right, but I think that if the Past-Presidents are to continue to vote on the election of Honorary Members and are not to continue members of the Board of Direction, that the matter should be expressed in a way in which there can be no possible doubt, and I do not think that if this amendment is passed in its present form that that will be the case. In one place our Constitution says what the Board of Direction is, and states that the Past-Presidents, all of them, have the right to vote for Honorary Members. In another place it states, unequivocally, that Honorary Members shall be elected by a unanimous vote of the Board of Direction, and does not provide anything else. The two things are not consistent and they will lead to trouble, and the matter can be remedied entirely by placing the words which are now to be put into one article in another, and as they are the same subject which is before the Society, though they would affect another article of the Constitution, I submit and claim that the Society now has the right to transfer an amendment from one place to ano-

ther. It is simply a method of making the statement absolutely clear, and I do not think we are bound by numbers and articles simply because they happen to be attached to paragraphs.

General CRAIGHILL.—I exceedingly regret the necessity of having to say so much, but I want to make myself clear. I am perfectly willing to admit the point that our Past-President, Mr. Morison, states. I am firmly of the opinion that the method he proposes to accomplish his result is unconstitutional at this time. If he proposes to advocate it here, let it be so, but it can be arranged constitutionally by a verbal amendment of my amendment which I will submit to the Convention for its consideration. In the first place, I wish to make a verbal amendment with reference to the five latest Past-Presidents and to insert the word "living"—"the five latest living Past-Presidents." I think that will commend itself to everybody, and with the permission of the Convention, I will insert that word at the proper place. And then, to cover the point, made by Mr. Morison, in a constitutional, way at this time I will modify my amendment with reference to the other Past-Presidents in this way—that "for the purpose of the election of Honorary Members all the Past-Presidents shall be members of the Board of Direction and for no other purpose." That covers Mr. Morison's point and settles the whole thing.

Mr. SKINNER.—Would it not be a simplification to pass this amendment and amendments of amendments as now suggested, and later on, after they are out of the way, to take up Mr. Morison's pertinent suggestion and amend that other clause of the Constitution which relates to Honorary Members so as to conform with the provisions of this amendment and secure uniformity in the procedure of election of Honorary Members.

The PRESIDENT.—I should rule you cannot change Article III of the Constitution under the notice which has been given.

General CRAIGHILL.—The Constitution is not open to amendment at this time except in the direction of these particular amendments now before us.

The PRESIDENT.—The question is called for and the resolution will now be read before voting, this vote being to pass it to a letter ballot vote of the Society.

The SECRETARY.—I have called attention to the changes made since it was last read. There has been one other:

"1. The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Secretary, and a Treasurer,"—that leaves the word "and" in, which was not in before;—"who with," instead of the word "and" before—"who with the five latest living Past-Presidents shall constitute the Board of Direction in which the government of the Society shall be vested and who shall be the Trustees, as provided for by the laws under which the Society is organized; that for the election of Honorary Members all of the Past-Presidents shall be members of the Board of Direction, and for no other purpose,

Discussion on Constitutional Amendments (continued).

unless any Past-President be disqualified by mental or bodily infirmity and the evidence of such disqualification shall be a written certificate from his attending physician or some officer of the Society."

Mr. MORISON.—There is a "that" in the beginning of the last sentence which wants to come out.

Mr. METCALF.—I think that is a little mixed in reference to the Past-Presidents being all members of the Board of Direction for the purpose of voting for Honorary Members and no other purpose. It conflicts with the fact that you have already made five of them members of the Board.

The SECRETARY.—It reads this way: "For the election of Honorary Members"—I guess that is right, too—"For the election of Honorary Members all of the Past-Presidents shall be members of the Board of Direction, and for no other purpose."

Mr. METCALF.—Now, if you strike out those words and have no other words, you will have it right.

C. FRANK ALLEN, M. Am. Soc. C. E.—In relation to one of the changes made, I think as it reads now it provides that the five latest living Past-Presidents shall be members of the Board of Direction. I wish to inquire what would happen if any of those Past-Presidents should cease to be members of the Society?

General CRAIGHILL.—I think the amendment reads: "Who is a member of the Society." It did in the original amendment as I read it. It has all been carefully considered, and I am quite sure it was in the original.

The PRESIDENT.—Are you ready for the vote? (Cries of "Question.") All who are in favor——

General CRAIGHILL.—One moment, Mr. President. Were those words struck out?

The SECRETARY.—I think I better read it all, sir.

Mr. MORISON.—I request that the amendment be read again.

The SECRETARY.—(Reading) "The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Secretary and a Treasurer, who, with the five latest living Past-Presidents who continue to be members, shall constitute the Board of Direction in which the government of the Society shall be vested, who shall be the Trustees, as provided for by the laws under which the Society is organized. For the election of Honorary Members all the Past-Presidents shall be members of the Board of Direction unless any Past-President be disqualified by mental or bodily infirmity"——

General CRAIGHILL.—I think, Mr. President, it would be better to substitute the word "except" for the word "unless."

The SECRETARY.—I will read that again:

"For the election of Honorary Members, all the Past-Presidents shall be members of the Board of Direction, except any Past-President be disqualified by mental or bodily infirmity"——

General CRAIGHILL.—"Who may be." Mr. President, if I may be permitted to speak, this illustrates exactly something that I was about

to propose, which I will not at this time; but I am not sure it would not be a good thing yet—to appoint a committee, not to refer this subject to a committee for discussion, but to appoint a committee which could report to us at our next meeting, whenever that is, to take all this and put it in proper shape.

(Cries of "No, no!")

Mr. Morison.—I would move that this meeting take a recess of five minutes, during which the President, Secretary and General Craighill revise this amendment.

(Cries of "No, no.")

Mr. Just.—I rise to a point of order; I think the question has been called for here.

The Secretary.—Shall I read this last half?

The President.—Yes, sir.

Mr. Allen.—Might I call attention to one point in relation to the last change? I think it now reads: "All living Past-Presidents who shall continue to be members." If so, it seems to me that the word "living" is entirely superfluous.

The Secretary.—It does not say so, sir; it is not here at all.

(Calls of "Question.")

The Secretary.—I will read it again, sir, so that you will see that "living" is not in it: "For the election of Honorary Members all the Past-Presidents shall be members of the Board of Direction, except any Past-President who may be disqualified by mental or bodily infirmity; and the evidence of such disqualification shall be a written certificate from his attending physician or some officer of the Society."

Mr. Allen.—Read at the beginning, if you please.

The Secretary.—At the beginning it says: "The five latest living Past-Presidents who continue to be members"——

Mr. Allen.—That is the point.

(Calls of "Question.")

Vote on Amendment 1 as amended.

The President.—All who are in favor of passing Amendment No. 1, as amended, to letter ballot by the Society, will signify it by rising and standing until they are counted.

(One hundred and ten members rose.)

The President.—All of contrary minds will now please rise and stand until they are counted.

(Six members rose.)

Amendments 2 and 3 amended.

Mr. Knap.—Mr. Chairman, I move now, sir, that amendments Nos. 2 and 3 be so changed as to conform in every respect precisely with No. 1 amendment as amended.

Mr. Seaman.—Mr. President, I wish to second that motion.

Mr. Allen.—Mr. President, I call for the previous question.

The President.—Are you ready for the vote? All who are in favor of that motion will signify it by rising and standing until they are counted.

(Ninety-two members rose.)

The President.—All of contrary minds will now rise, please.

(Fifteen members rose.)

The President.—The resolution is carried. Is there any other business to come before this meeting?

Mr. James Owen.—I would like to say, with regard to the trip up the Saguenay River, Mr. Peterson says there might be a probability of the company arranging to send a second boat for the surplus passengers, and if the gentlemen who do not get accommodations on the first boat will send their names to Mr. Goodell, we may probably be able to arrange for the second boat.

Election of Members of Nominating Committee.

The President.—Please wait for one more matter, gentlemen; the matter of nominations comes up and I do not think it will take any time. The reports of the committees from the several sections are in order now. Is Section No. 1 ready?

F. W. Skinner, M. Am. Soc. C. E.—In behalf of Section No. 1, I would say that the meeting was held last night and Mr. Henry B. Seaman was elected as its candidate to be presented to the Society to-day for election as member of the Nominating Committee.

Mr. Metcalf.—I move that the Secretary be directed to cast a ballot for Mr. Seaman.

The President.—If there is no objection, it is so ordered. District No. 2?

E. Kuichling, M. Am. Soc. C. E.—In behalf of the members of District No. 2, I would state that at the meeting called last evening they agreed upon naming Mr. E. H. Keating, City Engineer of Toronto, as their representative for the Nominating Committee.

The President.—And you make the same motion, that the Secretary cast the ballot?

Mr. Kuichling.—I make the motion also.

The President.—You have heard the resolution, gentlemen; if there is no objection, it is so ordered. District No. 3?

F. P. Stearns, M. Am. Soc. C. E.—Mr. President, twenty-three members met last night and unanimously voted to present the name of Mr. Edward W. Howe.

The President.—And you make a motion that the Secretary be authorized to cast the ballot?

Mr. Stearns.—Yes, sir.

The President.—If there is no objection, it will be so ordered. District No. 4?

Mr. Metcalf.—The Chairman does not respond. I don't know whether he has sent any representative or not; but Mr. Chester was unanimously selected by No. 4 to be presented, and I move that the Secretary be authorized to cast a ballot for him.

The President.—You have heard the motion, gentlemen; if there is no objection, it will be so ordered. No. 5?

Mr. Morris.—Mr. Chairman, Mr. Goldmark has been——

Henry Goldmark., M. Am. Soc. C. E.—I was requested to present the names of Mr. Onward Bates and Mr. Gouverneur Morris to the Convention as candidates for the Nominating Committee.

J. G. Van Horne, M. Am. Soc. C. E.—I move that Mr. Gouverneur Morris be nominated.

The President.—It is moved that Mr. Gouverneur Morris be elected by this Convention as member of the Nominating Committee.

Mr. Morison.—I move that Mr. Bates be the nominee. I do this without any prejudice to Mr. Morris, but I think that he received a pretty large number of votes. (Seconded.)

The President.—Then, I understand there are two motions, the one in favor of Mr. Morris having precedence, or shall I take them both together; that is the shortest way. All in favor of Mr. Morris, please rise and be counted.

(Forty-five members rose.)

The President.—All in favor of Mr. Onward Bates please rise and be counted.

(Sixteen members rose.)

The President.—Is the motion made that the Secretary be authorized to cast the ballot? However, the election is complete now.

A Member.—Who is it?

The President.—Mr. Gouverneur Morris.

J. A. Ockerson, M. Am. Soc. C. E.—District No. 6 presents the name of Mr. James Dun. I move that the Secretary be instructed to cast a ballot.

The President.—All in favor of the motion will say "Aye"; contrary, "No."

(The motion was carried.)

The President.—District No. 7?

H. B. Richardson, M. Am. Soc. C. E.—District No. 7 presents the name of Mr. A. M. Scott. I move that the Secretary be authorized to cast a ballot.

The President.—You have heard the motion and nomination; if there is no objection, the motion will be considered carried.

Mr. Ramsey.—I want to suggest the propriety of passing a resolution of thanks to the Canadian Pacific Railroad for its delightful trip.

William Starling, M. Am. Soc. C. E.—That is included in the resolution which I will now read:

"*Resolved*, that the thanks of this Society are hereby tendered to the members of the Local Committees of the Canadian Society of Civil Engineers; to the Lachine Rapids Hydraulic and Land Company; to the Governors of McGill University; to the Canadian Pacific Railway Company; to his Honor, the Lieutenant-Governor of the Province of Quebec, Sir Adolphe Chapleau, K. C. M. G.; to the Honorable Felix

Resolution of thanks passed.

Marchand, Premier of the Province of Quebec; to his Worship, the Honorable S. Napoléon Parent, Mayor of Quebec, and the members of the City Council; to D. J. Laliberté, Esq., Chairman, and the members of the Harbor Commission of Quebec; to the Honorable R. R. Dobell, P. C.; to the Directors of the Quebec and Lake St. John Railway Company; and to Horace J. Beemer, Esq., President Quebec, Montmorency and Charlevoix Railroad, for the courtesies extended to the Society during the Convention."

(The resolution was adopted.)

The SECRETARY.—There is one matter which ought to be brought up. The Board of Direction at its last meeting appointed a Special Committee to report briefly to the Convention the present condition of the new Society House project. Mr. Just, the Chairman of the Committee and the Chairman of the Building Committee, has such a report which will take a very few minutes to read, and there are also some pictures here showing the progress of work on the house and its condition at the present time.

Resolution on Dominion Day passed.

General CRAIGHILL.—A committee was appointed a little while ago at my suggestion consisting of myself, Mr. Starling and Mr. Stearns, to prepare a resolution recognizing the fact that this is, if I may use such an expression, although I am not an Irishman, the 4th of July—it is the 4th of July of the Dominion of Canada—is that the proper phrase to use?

(The Secretary: "Dominion Day.")

Dominion Day! I move that this Society, in recognition of the fact that this is the natal day of the Dominion of Canada, cordially express our best wishes for its continuance *ad infinitum.*

(The resolution was unanimously adopted by a rising vote.)

Mr. JUST.—Under the direction of the Board, I beg to report to you as follows:

Report on New Society House.

REPORT OF THE COMMITTEE APPOINTED BY THE BOARD OF DIRECTION TO REPORT TO THE ANNUAL CONVENTION THE PRESENT STATUS OF THE NEW SOCIETY HOUSE.

The last report to the Society in regard to the New Society House was made at the Annual Meeting, January 20th, 1897. At that time the contract for the erection of the building had been let and the work just started. For the first three months the building progressed rapidly, and there was every prospect that it would be ready for occupancy by the first of September. Owing, however, to a strike of steam fitters, and also one on the part of the plasterers, which at the present writing is still on, it is now thought that the Society will not be able to occupy the building at that time. The work of the mason has been practically completed, the brown coat of plaster has been on the walls for some time, and the white coat has been partly completed.

There are presented with this report two photographs taken June

23d, 1897, one of which shows a close view of the front elevation, and the other the depth of the house.

The following is a statement of the financial condition at the present time.

The total amount expended for the New Society House to date is as follows:

For purchase of property (complete).....	$80 000 00	
Vault privilege (complete)...............	937 50	
Excavation contract (complete)...........	4 500 00	
Legal expenses...........................	170 25	
Architectural competition................	1 976 73	
Sundries, circulars, etc.................	710 86	
Taxes....................................	684 80	
Interest.................................	2 550 82	
Architect's fee, on account..............	1 500 00	
Building contract, on account............	49 771 75	
Guaranteeing title to property, etc......	783 24	
		$143 585 95
This amount has been raised as follows:		
By cash subscriptions....................	$18 765 00	
Profit from sale of 175 copies "Historical Sketch"........................	533 06	
By sale of No. 127 East Twenty-third Street................................	47 764 16	
By loan from Mutual Life Insurance Co...	46 000 00	
Paid out of current funds................	30 523 73	
		143 585 95
There are still available the following:		
Unpaid subscriptions.....................	$1 265 00	
Due on sales of "Historical Sketch".....	290 00	
Estimated value of securities............	20 000 00	
		21 555 00

Based on a total expenditure (including decoration and furniture) of $190 000, the building can be made ready for occupancy with a debt of $70 000.

Respectfully submitted,

George A. Just,
Horace See,
Chas. Warren Hunt,
Committee.

New York, June 26th, 1897.

General Craighill.—I move that the resolution respecting Dominion Day be put into the hands of Mr. Peterson for transmission to the proper authorities.

(The motion was carried.)

The Convention then adjourned.

OPENING ADDRESSES AT THE TWENTY-NINTH ANNUAL CONVENTION.

The members and guests assembled in the Council Chamber of the City Hall, Quebec, at 10 o'clock.

Pro-Mayor Norris addressed the meeting as follows: "Ladies and Gentlemen, Members of the American Society of Civil Engineers: In the absence of his Worship the Mayor, the pleasing duty devolves on me of welcoming you to the ancient city of Quebec. I am sure that the gentlemen on whom rests the pleasure of entertaining you will do their utmost, and I trust that when your visit ends, you will carry with you most agreeable recollections of your sojourn among us.

"I have now the pleasure of introducing to you his Honor the Lieutenant-Governor of the Province of Quebec, Sir Adolphe Chapleau, who has kindly consented to address a few words of welcome to you."

Sir Adolphe Chapleau spoke as follows:

"Mr. President, Ladies and Gentlemen: I generally like to prevent any misapprehension when I am before an audience, even though it be in every way, as it is on this occasion, a very friendly audience. I have heard just now the representative of the Mayor of Quebec saying that I had gladly consented to make a short address to this meeting; so that there shall be no misunderstanding, I must state the position in which I stand. One of my old friends, a distinguished engineer of this country, Mr. Peterson, met me the other day in Montreal, and asked me whether I would like to be present at the reception to be given to the American Society of Civil Engineers, on their arrival in the city of Quebec. I have not generally the habit of being shy in meeting friends from whatever country they may come, so I said that I would, but on the distinct understanding that there would be no speech, at least on my part, and no address, as the Mayor's representative was pleased to say. I know that civil engineers are exceedingly regular in all their ways. They know what the right line is, and I would not like them to believe that at this moment I am going to make you a speech—not in the least. But a man whose heart is in the proper place is always able to say a few words of greeting on coming before such an assemblage as the one I see before me at this moment. So it is really a pleasure for me to second the motion, I might say, of the Pro-Mayor, and welcome you to this, the capital of our Province.

"It is with a great deal of pleasure that I have in years before—and I know it is not your first visit to our country nor to our Province—seen these meetings of men of intelligence, of work, of art and knowledge and science, as you are. It is always a pleasant thing to remember that in the past we have met them, and it is essential in the official position which I occupy at the present moment in the Province of Quebec, that I should see those gatherings and see those interchanges of courtesies between high professional men of the two neighboring countries.

"Gentlemen, you have come into this Province of Quebec under very favorable circumstances—I must bar the weather for to-day because certainly the weather engineer cannot have been at his post for a few weeks, or else he is mixing it too much with water for us at the present moment—but I say, you have come in very auspicious circumstances. Our Province has been for the last week or more in jubilation. There is a grand jubilee of our illustrious monarch, her Majesty the

Queen, which really has moved and has been the wonder of all nations for its magnificence, accord, peace, order, and all things worthy of the great sovereign whose jubilee it was. Our Province of Quebec is, at this moment, I might say, in jubilation. The Province of Quebec, which is in a large proportion French, has a special jubilee which it has been celebrating during the time of the jubilee of her Majesty; that is, the jubilee of the Society of St. Jean Baptiste. That society has been celebrating its diamond jubilee. It was instituted in 1835, in Montreal, in the garden of a gentleman who was a true Canadian—I may say a true French Canadian—since he was one of the founders of this Society, although his name was McDonald. This is the way we do in our country—I would not like to put you on your guard, but we have a quality which we try always to extend—that is, to assimilate to ourselves, to incorporate and to keep as much as possible our visitors for a longer time than they thought, perhaps, when they began their visit. I say, the Province of Quebec is in the jubilee of the great national feast. The Dominion will be celebrating to-morrow a kind of jubilee which is only the thirtieth jubilee—half a diamond jubilee—but at the same time it is a grand national holiday for this Dominion of ours, and you will see everywhere that the population is in the best possible disposition. But there was no need of that, ladies and gentlemen. I am sure you have experienced on former visits that in Canada, as well as in your own country, hospitality, the real comity of nations, is the password and habit of every citizen.

"These conventions of yours have a greater effect. Fortunately for us, since three-quarters of a century we have been at peace, and I hope we will pass, not only three other quarter centuries in peace, but that the balance of our national life in both countries will be passed in peace, in neighborly friendship, and if there are some clouds here and there passing which are caused, I would not say by lawyers—I am a lawyer myself, unfortunately, but not practicing, fortunately—if some clouds should pass by and some fears be entertained here and there that the peaceful condition may be troubled, I know that we shall always find in the United States and in Canada some man, well-meaning and well-knowing, and capable of engineering peace at any cost, but peace which is always protective of the best interests of the country. Yes, gentlemen, these visits of yours have this effect. We are friendly, as I say, politically; we are friendly socially, but these meetings, the interchange of views, the interchange of knowledge, the reports you receive of the progress of science, are such as create between the two neighboring countries a feeling that is stronger than people imagine and which is certainly one of the best and strongest ties of the friendship between the two countries. And I say, it is a happy idea that your different associations in the United States have adopted the system, which unites the useful and the pleasant, of visiting during the fine season—of visiting Canada during the fine season. There I suppose reciprocity exists, and our own associations, or members of them, are going to visit you. I say that reciprocity, a continued reciprocity in good neighborhood, reciprocity in feelings, reciprocity in science, reciprocity in those good sentiments of humanity which perhaps are as good, and I hope will tend in the future time to bring also the true social reciprocity and the true commercial reciprocity of the two countries which I hope one day we will see for the benefit of both countries. I am not here to discuss, still less to criticise, the politics of the two countries. There are men who know their business at that and who certainly are doing it to the best of their ability, and I am

sure in the best interests of their own countries; at all events, as they view them.

"Your Society is one of the most interesting that can visit our country. There are some men who pretend—I have heard some men who thought—that to be a civil engineer there was no need of great science, there was no need of very great work; a man could follow another engineer when he is building a railway or a bridge or a harbor or working in his office, and that is all. It is a great mistake, and I know that you engineers, whom a French writer has called, with great truth, the masters and the kings of the country, and the masters and the kings of the future of the country—that you in your profession require an immense amount of study and an immense amount of work, of labor, of observation. And you require to observe and to study all the laws of the physical world, the laws of Nature, the composition of bodies which are employed in construction and in different works which you are to direct. You are obliged to study the composition of the timber, of the earth, of the rock, of everything that you use—their elasticity, the action upon them of the atmosphere; in fact, all the laws of the physical world. You are obliged to study at the same time the science of higher mathematics; you are obliged to study precedents and to study comparisons between different works. Upon you devolves the great duty of insuring the safety of people in their buildings, the safety of cities and the safety of countries in the construction of great works—harbors, canals, dams and bridges, or any of those grand works. In fact, it is upon your profession that the safety of citizens, the durability of works depends—the durability of those great works that corporations are building. Mistakes in your work, as we have seen—but, fortunately, seldom—may cause great calamities and involve immense loss of life. It is upon you that we depend for all these things, and I think that the French writer was right in saying that you are the masters of the country and the masters of the future of the country in the building of the great works that you are superintending.

"Gentlemen, you come from the United States. We belong to the Dominion of Canada. You are a great, prosperous, powerful country, a country whose influence over the whole world has been felt in every way, especially, I might say, and most mightily, in the department of science to which you belong. Your engineers are known all over the world, as they have been working all over the world, and your profession stands, I might say, at the top of the great profession of civil engineering in the whole world. You are coming here, not to get instructions, but to exchange your views, and I am sure that our friends, the engineers of Canada, will profit by your visit in the intellectual field which you will traverse with them.

"I need not add anything more, as to do so would indicate that I was trying to do what I said I was unable to do on this occasion—namely, make a speech; but I thought I would say just those few words.

"I have only to add, ladies and gentlemen, that I hope the weather engineer will come to his post again and give you fine weather for the three days you are planning to be in our capital. You knew Quebec before. After this visit, I am sure that you will know it better and continue your appreciation of that city which is the pearl, the gem, of the cities to visit in this Dominion of Canada.

Pro-Mayor Norris then introduced the Honorable Felix Marchand, Premier of the Province of Quebec.

Mr. Marchand spoke as follows:

"Mr. President, your Honor, Ladies and Gentlemen: I may say that this unexpected appeal on the part of the presiding officer in this assemblage takes me rather by surprise, and I feel the necessity more than did his Honor just now of begging to be excused and of explaining that I am not going to make a speech, especially when I am called upon to be heard in the presence of so distinguished an assemblage as this, in a language that is not my familiar tongue. Still I cannot do otherwise than accept the invitation which has just been given to me, because I feel that as Premier of this Province it is my duty as well as pleasure to offer you the cordial hospitalities of our Province and to welcome you cordially, and, allow me to say, your better halves, who have been kind enough to accompany you.

"These visits of scientific men from one country to their colleagues in another country are always useful and beneficial to both of the countries interested. They are particularly beneficial to Canada. I trust that they are also beneficial to the great country which you represent, gentlemen. We have in our Province immense natural resources which are, I might almost say, unexplored, many of them are unexplored. A few of them have been partially explored. They present great riches, which, by their development, will turn to our benefit and will also, I believe, be of great benefit to our neighbors. We have the resources, and I think I can modestly say that we can count upon you for a certain contribution of an important part of the capital which is required to explore these resources and to turn them to the benefit of our country and the benefit of the capitalists and engineers and men of science of our neighboring country, who will find it to their advantage to come and help us in the working of these natural resources. So I think, gentlemen, that I can say with the certainty that I am not in error, that these resources which are not sufficiently explored at this moment will, if you come to our aid, turn to the benefit of both countries.

"This fraternity between engineers is certainly a good omen for the future. Your interchange of views respecting the two countries, which in many respects have a great similarity—our interests are greatly similar—will certainly turn to our mutual benefit. It will have especially as a result the establishment of those friendly feelings and that friendly intercourse between the American engineers and the Canadian engineers which will turn to the mutual benefit and progress of our countries, and, I hope, favor the fortunes of those who will undertake to come and help us in the exploration and development of the natural resources which I spoke of a minute ago.

"Gentlemen, I will not go any further. If his Honor, before the eloquent speech which he pronounced a minute ago, found it a necessity to apologize, I must say that I have to make an apology also, and I think I am more justified in making it than he was. Gentlemen, as I did not expect to be called upon to make a speech here to-day, I merely, before sitting down, wish to repeat the words of welcome which I addressed to you when I commenced, and to say that I am sure that all our Province will be happy to see that you take such an interest in it as to come in such numbers, and we feel especially grateful to see that you have thought it proper to be accompanied by the ladies whom I see here, and who certainly, I hope, will return with a good impression of it and of its population, which you are kind enough to say has a proverbial reputation for gallantry."

President Harrod replied as follows:

"Your Honor, your Worship: In behalf of the American Society of Civil Engineers, allow me to extend its thanks to you for the kindness which you have expressed and the welcome you have extended. We appreciate the character of the relations that allow us to come here as to a part of our own country and to meet you as our fellow countrymen. We will have no arbitration with you, for the good reason that there is nothing to arbitrate. While we retain our appreciation of the poet's expression that 'One touch of Nature makes the whole world kin,' we submit that the railroads, the steamships, and the other works of the civil engineer have given a reality and an extension to the sentiment that it did not at first convey. Our kinship with you is one of sentiment, reinforced with 90-pound steel rails, live wires, and other appliances of civilization and commerce. I thank you again for your welcome."

REPORT ON UNIFORM STANDARD TIME.*

By SANDFORD FLEMING, M. Am. Soc. C. E.

When the American Society of Civil Engineers met in Canada 16 years ago, I had the honor to submit a paper on "The Reckoning of Time, in its Relation to the Operating of Railways and other Great Lines of Communication." The younger members of the Society who are with us here to-day will be less familiar with the difficulties which then existed than some of my friends who are present. I do not propose to dilate upon these difficulties. Suffice it to say that in less than three years after the period referred to and largely through the instrumentality and influence of this Society, the railway managers adopted what is known as Standard Time, or the hour-zone system of reckoning. By this expedient the difficulties which formerly prevailed were to a large extent removed.

But the scheme of time reform favored by this Society was not wholly adopted by those who controlled the railways; one step only, although a very important step, was taken. The second half of the reform yet remains to be systematically carried out. I refer to the 24-hour notation. This Society has moved in the matter from time to time and has done much to secure the adoption of the new notation eventually; if it has not yet influenced the adoption of the 24-hour notation throughout the United States, it has by its publications and otherwise directed attention to its advantages with so much effect that the reform has been taken up in other countries, and to-day it is universally in force on the railways in India, in China, in Italy, in Belgium, and judging from the expression of opinion by railway men of various European countries at the International Railway Congress held in Vienna last December, it is fully expected that this advance in time-reckoning will soon be common throughout Europe. In Canada the new notation has been employed in the operation of the Inter-Colonial, the Canadian Pacific and other railways during the past 10 or 12 years, and moreover the advantages are so marked that there is not the smallest probability of the old system being again used.

It will be remembered that the President of the United States assembled an International Conference in 1884 to consider the subject of time reckoning generally. The conference met at Washington and after

* This was presented at the Annual Convention, June 30th, 1897, and accepted by the Society as a progress report of the Committee on Uniform Standard Time. See p. 83.

a month's deliberation passed a number of resolutions which were held to be wise and expedient. The sixth resolution has not yet been adopted, although those whom it chiefly concerns are practically unanimous in its favor. I allude to the class of men engaged navigating every sea. While it concerns seamen more especially, it is not without interest to members of this Society; it indeed concerns the whole community as it indirectly bears on the other half of time reform, advocated by this Society, which has not yet been systematically adopted throughout the United States.

The sixth resolution of the Washington Conference involves the unification of time at sea, and its general adoption by the nations of the world would be a great step towards the universal substitution of the 24-hour notation for the present usage of reckoning the hours by half days in two series of 1 to 12.

The recommendation of the Washington Conference is that the astronomical and nautical day should be brought into agreement with the civil day; that is to say, the two former should cease to begin at two separate noons and start from the same midnight as the civil day, so as to give concurrent dates. So soon as that agreement shall be effected, the astronomical day will be the civil day, with this distinction, the hours of the astronomical day as now reckoned in one series from 1 to 24 will continue to be so reckoned.

This circumstance makes it clear that the new astronomical day would be in absolute agreement with the civil day, having the hours reckoned according to the 24-hour notation. Obviously thus, in considering the reckoning of time by land and sea, the adoption of the sixth resolution of the Washington Conference may be viewed in the light of a compromise, and although that resolution directly refers more particularly to navigation, indirectly it bears on affairs on land as well as on sea, and in its adoption it may reasonably be assumed that no long period would elapse before the advantages of the simple and rational notation used at sea would extend to lines of transportation on land everywhere.

Since the date of the Washington Conference, 13 years ago, much correspondence on the subject of the sixth resolution has passed between the nine nations chiefly concerned and by astronomers all the world over. It has been found that, although a few eminent and very influential astronomers have not been in favor of any change, astronomers as a class are quite prepared to accept it, provided arrangements be made for giving it effect at the epoch when this century passes into the twentieth century, now not far distant.

With respect to the nine nations chiefly interested, that is to say, the nine powers regularly publishing ephemerides, I can most briefly explain the attitude assumed by them if the meeting will allow me to read an extract from a report of a joint committee of the Canadian Institute and the Astronomical and Physical Society of Toronto.

"Of these nine powers, six have formally given their assent to the proposed change. The remaining three, while they have not signified assent, have not expressed dissent.

"The six nations formally assenting to the adoption of the recommendation of the Washington Conference on the first of January, 1901, are: Austria, Brazil, France, Great Britain, Mexico and Spain. Of the remaining three, Germany and Portugal have not, so far as is known, sent any reply. A brief communication has been received from the Secretary of State at Washington, simply stating 'that the members of the United States Naval Observatory are adverse to the proposition,'

and, at the same time, he sends a copy of the adverse report. This is the only report of a negative character which has been received, and it is the more surprising as this report is entirely at variance with the position taken by the United States throughout the movement for reforming the time-reckoning of the world during the last fifteen years. The United States have, indeed, taken a prominent part in the movement. Two societies, comprising in their ranks some of the most eminent scientists of the country, have actively promoted it from the commencement—the American Meteorological Society and the American Society of Civil Engineers. Moreover, both Houses of Congress have taken joint action in the matter. It was under the provision of an Act of Congress that the President assembled the International Conference of 1884. At that conference, it was the five distinguished delegates nominated by the Government of the United States who introduced the proposal respecting the Astronomical Day, a proposal which was carried without a dissenting voice by the representatives of the twenty-five nations constituting the Conference. It is to the United States we trace some of the first steps taken to establish an acceptable system of reform in the reckoning of time adaptable to the whole world. It is certainly to them that we owe the first national recognition of the movement and its first application to every-day life, that is to say, the joint-resolution passed by Congress in July, 1882, and the action of the gathering of railway managers in Chicago, which resulted in the hour-zone system of time-reckoning going into force throughout North America on November 18th, 1883.

"With all the facts before us, it is impossible to consider that the adverse report of the United States Naval Observatory fairly represents the mind of the United States Government, of Congress, or of the people of the United States. The objections brought forward in this report are of old date and at various times have been answered—by the Bureau des Longitudes of France in an official report (*vide* Cosmos, February 3d, 1895), endorsed by the French Government, May 6th, 1895—by the reports of the Joint Committee of April 21st, 1893, and May 10th, 1894, copies of which have been transmitted to the Home Authorities; by the Astronomer Royal in a report to the trustees of Greenwich Observatory, which points out that the proposal can be easily introduced and with decided advantage to observers; by a former superintendent of the United States Naval Observatory, Commodore Franklin, December 11th, 1884, in a communication transmitted to Congress with other documents by the Secretary of the Navy, February 17th, 1885.

"These several documents amply refute all the objections to the proposal and render any discussion of them in this report unnecessary. Their best answer is the fact that the governments of six ephemerides publishing nations, comprising some of the most conservative countries in the world, have, under the advice of their ablest men, recognized the advantages of the proposal and have assented to it being carried into effect. The attitude assumed by the United States Naval Observatory is so decidedly different from that of a few years back that the sole explanation which can be made is that the personnel of the Observatory has changed.

"Immediately after the Washington Conference of 1884, Commodore Franklin, the head of the United States Naval Observatory, desiring to give effect, without delay, to the resolutions passed, issued instructions to the observatories of the United States to bring Astronomical Time into agreement with Civil Time. The officer was supported by three-

fourths of the leading astronomers of the United States, who, doubtless, felt with him that it would be becoming on the part of the nation which had assembled the Conference to be the first to accept and give practical effect to its wise recommendations. There was one exception, however, Professor Simon Newcomb, who raised strong objections to any departure from the old system. This gentleman, whose name is attached to the adverse report of recent date, as Professor of Mathematics, U. S. N., and director of the Nautical Almanac, did not, in objecting to the instructions of Commodore Franklin, express his adverse opinion on the general question for the first time. In 1882, two years before the Washington Conference, the American Society of Civil Engineers formulated a scheme of time reform, which, in its essential features, has come into use not only throughout the North American Continent, but also over large parts of Europe, Asia and Australia. In order to ascertain the views of scientific and practical men, this society sent out circulars asking an expression of opinion respecting the proposed measure. A series of questions were drawn up and answers to them were respectfully invited. Among the many replies received and placed on record in the publications of that society there is one from Mr. Simon Newcomb, whose words read strangely in the general record of assent and approval with which the measure was welcomed throughout the United States and Canada. They are appended.*

"The publications of the American Society of Civil Engineers affirm that replies were received from all parts of the United States and Canada and that 99 per cent. expressed opinions diametrically opposed to those of Mr. Newcomb. The unanimity of opinion was indeed remarkable. In one respect, Mr. Newcomb stood alone in his antagonism to this scientific reform. In marked contrast to his objections, we have the breadth of view and general enlightenment of the members of the societies named, and of the managers of the great lines of transportation by land and water throughout the United States, the men who in 1883 adopted the Standard Time System. We have in still more marked contrast to the views of Professor Newcomb the spirit which moved the highest constituted authorities, the Senate and the House of Representatives, in passing a joint resolution requesting the President of the United States to assemble representatives from every civilized nation to consider the very questions which find so little favor with Mr. Newcomb. These remarks go to prove that this gentleman holds conservative views in the matter of time reform peculiarly his own, and that it is impossible to accept a report expressing his opinions on this question as representing the voice of the United States. The evidence shows that the United States stands in the front rank in support of this important movement, and with respect to the proposed change in the Astronomical Day, a letter from the Secretary

* Replies of Mr. Simon Newcomb, Washington, to queries issued by the Special Committee on Standard Time of the American Society of Civil Engineers, 1882.

EXTRACT FROM THE PUBLICATIONS OF THE SOCIETY.

Question 3.—Do you consider it advisable to secure a Time System for this country (the United States) which would commend itself to other nations and be adopted by them ultimately?

Answer (by Mr. Newcomb).—No. We don't care for other nations; can't help them; and they can't help us.

Question 4.—Does it (the scheme for regulating Time) seem to possess any features which generally commend themselves to your judgment?

Answer (by Mr. Simon Newcomb). A capital plan for use during the millennium. Too perfect for the present state of humanity. See no more reason for considering Europe in the matter than for considering the inhabitants of the planet Mars.

of the Navy to Congress, dated February 17th, 1885, brings out the fact that although the execution of the order was subsequently deferred until a general agreement could be reached, a general order was actually issued on December 4th, 1884, by the head of the Naval Observatory, to begin the Astronomical Day at midnight in accordance with the recommendation of the Washington Conference of that year. Moreover, it may be added that the recommendations of the Washington Conference were endorsed by the President of the United States in his message to Congress of January 9th, 1883.

"In view of the facts narrated, the Joint Committee respectfully conceives that it is fully warranted in the opinion that the United States, as a nation, may be truly considered to be one of the nine ephemerides publishing nations in favor of the proposal to bring the Astronomical Day into agreement with the Civil Day."

The expression of opinion by the Joint Committee, which I have submitted, was brought to the attention of the British Government, but the latter while willing to make the change provided other nations publishing ephemerides are prepared to take the same action, has in effect declined to take any further step under present circumstances. The British Government having already approached the Government of the United States and invited its co-operation with the other assenting Powers in effecting the desired change, nothing further can be done unless and until the assent and co-operation of the Government of the United States be obtained.

As Chairman of the Special Committee of this Society I feel it my duty to state plainly how the matter now stands. I will conclude these remarks by reading a letter which I have within the past two weeks received from Commander Francis M. Green, U. S. N., and leave the meeting to judge what action, if any, should be taken by this Society. The letter is on a subject of so much public importance that with your permission I feel that I may with propriety submit an extract to your attention. The letter is dated Boston, June 15th, 1897.

"While on a visit to my friend, Dr. Mendenhall, at Worcester, my attention was called to the admirable pamphlets on the Unification of Time, in which matter you have manifested so much public spirit.

"If it would not be considered officious, I should like to add my testimony emphatically in the affirmative in answer to all four of the questions on page 30, submitted to master mariners for their opinions. From 1873 to 1883 I was, under the direction of the United States Navy Department, engaged in determining telegraphically secondary meridians all over the world. These meridians, some forty in number, have been accepted by the United States Government and the British Admiralty, as well as other authorities, as fundamental. From this experience as well as from navigating ships all over the world for the last forty years, I have been impressed with the inconvenience and absurdity of having three several starting points for the commencement of the day—nautical, civil and astronomical.

"May I suggest that the new superintendent of the United States Nautical Almanac, Professor W. W. Hendricksen, U. S. N., was educated as a seaman at the United States Naval Academy and is a very reasonable and sensible man? He may, I think, look at the matter in a different light from Professor Newcomb."

I have pointed out that this Society was one of the first to move in the matter of time reform in connection with operating the railways of the country with which so many of its members are variously associated. The subject has expanded in interest until it now concerns all

the nations of the world. This Society has kept alive a special committee during these sixteen years to deal with the subject. That committee has done everything in its power agreeably to the wishes of the Society to promote the important movement. The work of the committee in behalf of the Society remains incomplete until standard time in all its fullness be generally adopted. I respectfully submit, therefore, that the American Society of Civil Engineers might at the present time very fittingly take such action as may be deemed advisable to move the United States Government to give its assent to the recommendation of the Washington Conference of 1884, as contained in the sixth resolution of that conference.

A GREAT HYDRAULIC LABORATORY.*

By E. A. Fuertes, M. Am. Soc. C. E.

I desire to state at the outset, that in addressing you I do not intend to ask you to listen to an advertisement. This would be an undignified proceeding, that I desire to disclaim. I simply bring the news of the existence, in the State of New York, of a hydraulic laboratory superior to anything built hitherto in any country, which will be open to the inspection, and under some conditions, use, of any engineer desiring to conduct such experiments as he may need in the incidents of his practice, or who may make inquiries or furnish data upon experiments of importance that he may desire to have made. This laboratory has been created only for the advancement of hydraulic science.

There are but few fields of engineering practice upon which more has been written than upon hydraulics; in fact, our hydraulic literature is very full, and, as it may be easily surmised, not much of it is useless; for to deal effectively with water it is necessary to acquire accomplishments incompatible with the production of such platitudes as afflict many other specialties in engineering. It has been believed that the limits reached in the progress of hydraulics are due mainly to the lack of opportunities for proper experimentation on a suitable scale, and this is all the more strange, since almost every nation on the face of the earth is obliged to spend, in the aggregate, fabulous sums of money in the improvement of rivers, harbors and coast defences. Yet a large number of unsolved doubts and of tentative hydraulic works are forced upon the engineer, because his problems become indeterminate by the variety of conditions found in Nature, which, in combination, make their solution almost hopeless. This great laboratory, now under way, will enable the engineer to devise any single, simple problem; and, after a study of its conditions, add to the original problem, such disturbing new conditions as may enable him to discriminate between the effects of individual simple causes and their combined interaction.

I know of but a single effort made to study a portion of a river by the reproduction of its conditions in a model; but in this case, the effect of water acting upon a very small model of the Seine, between Rouen and Havre, could not represent anything like proportional circumstances to the conditions in action; since the effect of a current of actual water upon a microscopical river, with tangents and curves, and a soil varying from rocks to silt, could not be taken as an index of what the water volume, and current force, would produce upon the

* A statement made at the Annual Convention, June 30th, 1897. See p. 84.

actual river itself, even though this model of the Seine has proved very useful to illustrate the effect of training walls upon tidal action. Again, a hasty survey of the causes of failure in many of our river improvements upon the Danube, Rhine, and Rhone and our own Mississippi, reveals the necessity of better data, and a settlement of the long disputed theories of transportation by dragging and by suspension in water.

A recent engineering scandal might have been avoided, and the profession spared an unnecessary war between some of its most worthy and eminent engineers, if sufficient experimental data had placed beyond doubt the conditions of delivery through large riveted water conduits, which is as different from its action in ordinary city piping as the latter is different from the results obtained in a laboratory with small glass tubes.

It would be unnecessary to add more reasons to justify the existence in this country of such a laboratory as I shall presently describe very briefly.

This laboratory is located mainly on the south shore of a stream with precipitous banks, having a minimum delivery of 12 cu. ft. per second, and a maximum delivery of nearly 5 000 cu ft. per second. From 2 000 to 3 000 cu. ft. per second can be relied upon during the best seasons for work. A dam across the stream can be made to store from 50 000 000 to 70 000 000 galls. of water.

At the south of this dam a canal, blasted out of the rock, is provided with gates, and extends down stream some 500 ft. The canal is 16 ft. wide and able to carry a depth of 10 ft. of water, which can be delivered into it under 20 ft. of head. Behind the entrance gates, baffle-boards and other contrivances control desirable conditions for the entrance of the water into the canal. The weirs with which the canal is provided can be calibrated and replaced under identical conditions, using the water-tight canal to measure the volumes delivered. Within the walls, special contrivances to be read by filar micrometers are placed at short intervals from each other, to give the height of the water along the canal with precise accuracy. The canal can empty itself at pleasure, either in the shape of a water-fall about 80 ft. high, or into a steel pipe 72 ins. in diameter and over 70 ft. in length, which pierces vertically under it the roof of a building in which can be conducted many experiments better performed under shelter. Also, by the side of the canal and parallel to it, a steel pipe 3 ft. in diameter can deliver its water at will either into the 6-ft. steel pipe, the canal, or directly into another building, to supply water pumps and dynamos for lighting and water supply purposes, under about 80 ft. of head.

Half way down the 6-ft. steel pipe, a turret-like structure makes convenient the conducting of experiments to determine coefficients of efflux in thin plates, all forms of orifices, tubes, nozzles, valves, cocks, etc., up to 4 ins. in diameter, and under different, constant and variable heads. In the building below, on the floor of which the stand-pipe rests, special castings and reducers can be attached to the steel pipe, capable of taking pipes and valves from 6 ins. to 4 ft. in diameter. Along the bottom of the creek there is room for experimenting upon these larger pipes for straight lengths up to 2 000 ft., and upon indefinite lengths, beyond this distance, with both vertical and horizontal curves. A number of Venturi meters, which do not use electrical counters, are provided for experiments of this nature.

Upon the walls of the canal itself, two rails support a truck provided with a small dynamo that can be adjusted to run the truck at

suitable velocities. A chronograph marking seconds is made to register automatically the travel of the truck at every 10 ft. of its run, and, therefore, its position and velocity can be determined with any desirable degree of accuracy. The water of the canal can be so regulated as to be either perfectly quiescent, or its velocity can be controlled by the amounts allowed to enter the upper weirs of the canal and the relative positions of the down-stream weirs. The height and conditions of the position of all the weirs can be regulated with the greatest nicety.

While it would be impossible at present to detail all the experiments that experience with this laboratory may develop, I may mention incidentally the following programme :

(1) Studies upon the dragging and suspending power of water at various stages of its saturation with sediment.

(2) The effect of transverse, longitudinal, and submerged dams, under standard conditions, which may be modified at will by disturbing influences covering any variety of complications.

(3) The determination of corrections to be made in the beds of streams to give them the most stable longitudinal profile.

(4) Study upon the conditions of such rivers as build their minor beds above the major bed. Major Leach's recent paper upon "What the Mississippi is, and what it needs" offers numerous suggestions of usefulness for this laboratory.

(5) Study of littoral cordon formation, and of channels, bars, and deltas, and of the deposition of sediment from rivers entering into quiescent water, and against high tides.

(6) Study of the conditions affecting the length of tangents and degree of curvature in natural and constrained water courses, looking to securing permanence of channels and depths of water.

(7) Studies upon the delivery and conditions of the water-shed of the stream and the tributaries which feed the canal, in reference to the amount and kinds of suspended matter by floods, the inter-relations of the deliveries of the tributary floods, and such studies as may prove useful for determining the coefficients of flood volume, lengths of dams and spillways, and height of floods over them, so as to perfect the formulas for the delivery of water-sheds, if this be possible. The water-shed of this canal covers 117 square miles, which will be most carefully surveyed topographically and geologically.

(8) With this canal experiments can also be made upon the rating of current meters, and general studies upon the motion of water in open channels, in pipes, and over weirs, under variable conditions of velocity, materials of the bed, conditions of surface, contractions, and heads.

(9) The determination of the resistance to the motion of boats in canals in reference to their respective cross-sections, effect of waves, etc.

(10) Experiments on water-jets, forms of water-wheel buckets, ratios of areas and forms of propellers, including water-jet propulsion; which subjects, by themselves, will give rise to a large number of investigations.

(11) Experiments on the construction and efficiency of water and other motors, including water meters.

(12) Effects of form and condition of the surface of the vessels upon their speed and motive power required.

(13) The uses of this laboratory are not restricted simply to questions strictly classified as of hydraulic importance. For example, on the sanitary side, the relations that should exist between the grade of a sewer, its size, and the volume of flush water required to produce a

given effect, are almost entirely unknown. The work of S. H. Adams, just published, does not supply the needs of sewer designers with needed generality. The equipment of this laboratory can settle the conditions required to determine how far down grade a definite volume of flush will be effective, under the varying conditions of this problem.

(14) In this sanitary connection also, a new science is looming up properly called Engineering Biology. Hitherto the biologist has been interested mainly in the genesis of life, and his studies have had no decided trend offering information which is indispensable for the purposes of the water supply engineers. On the other hand, the physicians mainly interested in general pathology and therapeutics, has given little attention to the modes of life and death of the infinite number of micro-organisms found in water, which prey upon human health. But the engineer, who is to supply drinking water to cities and makes it more or less stagnant behind huge dams and impounding and distributing reservoirs, has had, hitherto, no definite knowledge of the best methods for fostering and preserving a standard of purity in his water supplies.

Far be it from me to ignore the splendid work done by the biologist and physician in their lines. I have reference only to the work not yet done, and needed to be done, under the special view of the engineer; and since impure water is the cause of innumerable deaths, the opportunity that the laboratory offers for many important studies will be easily appreciated.

(15) This very much enlarged laboratory can now continue, under the best auspices, investigations under way for some time past, based upon the universal theory that all living beings derive their sustenance, at least in part, from other living beings; and that certain conditions of temperature, light, and plant life, either arrest or foster their growth. An effort is being made to find out how to populate our drinking water with forms of life, capable of destroying dangerous organisms, and yet strong enough in their struggle for life to survive in sufficient numbers for this beneficial purpose under protective conditions, as yet difficult to control. I may say that although this question is far from being solved, with unfiltered waters especially, its prospects are indeed hopeful. The hydraulic laboratory I am describing lends itself admirably to studies of this nature.

(16) Many of the labors undertaken by the Boards of Health of Massachusetts and Michigan, which are an honor to this country, can be extended and made useful much more rapidly here than under the cramped conditions and lack of resources and the political corruption which now hampers the efforts of some of our best Boards of Health. I cannot but say, however, that with the above two exceptions, adding possibly the Boards of Health of Connecticut, Kentucky, Louisiana and Rhode Island, all the other Boards of Health in this country are most disappointing institutions.

Among the Boards of Health of thirty-nine States, one (consisting of a physician and one lawyer), investigates the origin of epidemics; another, composed entirely of non-professional men, propagates vaccine virus; a third, made up of physicians entirely, studies typhoids and diphtheria; a fourth, made up of physicians and non-professional men, investigates diphtheria and tuberculosis; a fifth, composed of physicians, lawyers and civil engineers, studies in Massachusetts the actions of filters, etc.; the Michigan Board of Health studies the relations of climate to disease; yet another only distributes vaccine; and lastly, another, made up of physicians and civil engineers, studies

diphtheria and consumption. The States appropriate for the work of the Boards mentioned the sum of $92 200. This insignificant sum is the only one which supplies, in some measure, data for the advancement of sanitary science. The total expenditures of thirty-nine other Boards of Health, as ascertained by correspondence with all the States of the Union, amounts to $256 900, most of which fails to fulfill any reasonable expectations as to usefulness, with the exceptions above mentioned of Massachusetts, Michigan, Louisiana, Kentucky, Connecticut and Rhode Island.

I do not intend to cast any reproach upon the Boards of Health of the country, for I know of some, and suspect the nature of many, of the difficulties against which they are obliged to contend. I wish only to point out that the entire subject, and management, of our Boards of Health is in a chaotic and hopeless condition of inefficiency, and will remain so as long as they are left to work by themselves under the loose and improper conditions which obtain in nearly every State of the Union, owing to that lack of unanimity of public sentiment which cannot be obtained without sufficient scientific backing. It is hoped that this laboratory may aid the Boards of Health in directions as yet unattainable by reason of expense and lack of facilities; rescuing some of them from the control of politicians, and enabling them to organize with a suitable personnel, on account of the proofs that can be given to strengthen their claims upon the attention of the people, as the result of experiments which this laboratory will be able to furnish.

The location of the hydraulic laboratory which I have endeavored to describe briefly is a most fortunate one; indeed, it is estimated that if its natural conditions were not so favorable, $3 000 000 could not provide the resources that Nature offers almost without price, and are indeed priceless.

It gives me pleasure to state that this hydraulic laboratory, located at Cornell University, is now and will always be at the service of any engineer, municipalities or other corporations desiring to conduct experiments tending to advance the interests of hydraulic or sanitary science. The only conditions that may be imposed, are, that such work as may be required, be done without expense to the University beyond the use of the equipment in the place; and that it must not interfere with the regular work of its students. I may add, to anticipate a natural question, that the work done by undergraduates in the large laboratory or in the small hydraulic laboratory under the roof of the College of Civil Engineering refers mainly to experiments having no other purpose than to carry on some of the experimental work hand in hand with the class-room theories. The work of investigation is carried on, mainly, not by undergraduates, but by engineering practitioners and a considerable number of graduates, who, having found in their practice some point needing investigation, return to the University where they can enjoy the quietude and the resources in books, equipment and opportunities that it is impossible to obtain or use when engaged with the absorbing cares of a busy professional life.

I shall be ready at all times to answer questions upon this subject, and I feel authorized in the name of the President of Cornell University, to invite any and all members of this body to visit and inspect this great hydraulic laboratory, and to use it freely and often in the interests of its only object: "To Foster the Progress of Hydraulic Science." It is expected that the work on this laboratory, which has been for some months under way, and is being done by contract, will be finished towards the end of next autumn.

EXCURSIONS, ETC., DURING THE TWENTY-NINTH ANNUAL CONVENTION.

The excursions during the Twenty-ninth Convention were in the hands of the following local committees appointed by the Canadian Society of Civil Engineers:

In Montreal: P. Alex. Peterson, Ernest Marceau, Percival W. St. George, John Kennedy, George Herrick Duggan and W. McLea Walbank.

In Quebec: St. George Boswell, *Chairman;* G. F. Baillargé, A. Rhodes, Louis Vallée, Edward A. Evans, Thomas Breen, E. A. Hoare, Ulric Valiquette, O. S. Sterling and C. E. Gauvin, *Secretary.*

On Tuesday, June 29th, an excursion was made in carriages from Montreal to the works of the Lachine Rapids Hydraulic and Land Company. A number of members and guests visited the Engineering and Physics Buildings of McGill University, which were opened to the inspection of the Society through the courtesy of the Governors of the University. At 14 o'clock the members and guests left Montreal on a special train tendered by the Canadian Pacific Railway Company, which reached Quebec about 18.30 o'clock.

On Thursday, July 2d, the Quebec Harbor Commissioners tendered the use of two steamers for a visit to the Harbor of Quebec and a trip up the St. Lawrence to "Beauvoir," the country seat of the Hon. R. R. Dobell, P. C., who invited the Society to a garden party. The return was also made by steamer. In the evening a reception was given by the Society at the Chateau Frontenac.

On Friday, July 3d, an excursion was made in the morning, by invitation of his Worship the Mayor and the members of the City Council, to Chateau d'Eau, at the headwaters of the St. Charles River, whence the city draws its supply of water. In the afternoon, an excursion was made on a special train tendered by Horace J. Beemer, Esq., President of the Quebec, Montmorency and Charlevoix Railroad Company, to the Shrine of Bonne Ste. Anne, stopping on the way to view Montmorency Falls.

THE ATTENDANCE AT THE TWENTY-NINTH ANNUAL CONVENTION.

The following 168 Members were in attendance:

Allen, C. Frank ......Boston, Mass.
Archibald, P. S....Moncton, Canada.
Averill, Frank L...Washington, D. C.

Bacon, John W......Danbury, Conn.
Baird, Howard C... Phœnixville, Pa.
Baker, Holland W.....St. Louis, Mo.
Baldwin, W. H.......Yonkers, N. Y.
Bell, Andrew.........Almonte, Ont.
Bissell, H. ....West Medford, Mass.
Bontecou, Daniel...Kansas City, Mo.
Bonzano, A........Philadelphia, Pa.

Brackenridge, J. C...Brooklyn, N. Y.
Brackenridge, W. A.,
Niagara Falls, N. Y.
Brackett, Dexter.......Boston, Mass.
Breuchaud, Jules.....Yonkers, N. Y.
Brinckerhoff, H. W...New York City.
Buck, L. L...........New York City.
Buck, R. S.......Niagara Falls, N. Y.
Burpee, Moses..........Houlton, Me.
Burrows, Geo. L.....Saginaw, Mich.

Carson, W. W......Knoxville, Tenn.
Chapin, L. E.............Canton, O.
Chester, John N.......Pittsburg, Pa.
Chittenden, S. H...East River, Conn.
Clark, L. V., Jr.....Philadelphia, Pa.
Codwise, Edward B..Kingston, N. Y.
Coffin, Freeman C.....Boston, Mass.
Colby, B. H..........St. Louis, Mo.
Cooper, Theodore....New York City.
Coulson, Ben...........Sidney, Ohio
Craighill, Wm. P.,
Charlestown, W. Va.
Crandall, C. L..........Ithaca, N. Y.
Croes, J. J. R........New York City.

Dalrymple, F. W..Hornellsville, N. Y.
Danforth, Frederic......Gardiner, Me.
Davis, Arthur L......St. Albans, Vt.
Deans, John Sterling.Phœnixville,Pa.

Eayrs, Norman W.....St. Louis, Mo.

Fisher, Clark.........Trenton, N. J.
Fisher, Edwin A....Rochester, N. Y.
Flad, Edward.........St. Louis, Mo.
Flagg, J. Foster... ..New York City.
Fleming, Sandford..Ottawa, Canada.
Foyé, A. E...........New York City.
Freeman, John R...Providence, R. I.
Freeman, F. L....Washington, D. C.
French, Alexis H...Brookline, Mass.
French, J. B..........Richmond, Va.
Frizell, Joseph P......Boston, Mass.
Fteley, A............New York City.
Fuertes, E. A..........Ithaca, N. Y.

Gates, Christopher L...Toledo, Ohio.
Gayler, Carl..........St. Louis, Mo.
Goldmark, Henry,
North Long Branch, N. J.
Goodell, John M.....New York City.
Gowan, Chas. S.......Yonkers, N. Y.
Guthrie, Edward B... Buffalo, N. Y.

Haines, Henry S.........Atlanta, Ga.
Hains, Peter C........Baltimore, Md.
Hannaford, E. P...Montreal, Canada.
Haring, J. S.............Nyack, N. Y.
Harlow, James H.,
Edgewood Park, Pa.
Harris, C. M........ New York City.
Harrod, B. M.. . .New Orleans, La.
Hemming, D. W.....New York City.
Hering, Rudolph....New York City.
Hider, Arthur......Greenville, Miss.
Hilgard, K. E...... .St. Paul, Minn.
Hinckley, J. F.........St. Louis, Mo.
Hodgdon, Frank W....Boston, Mass.
Howe, Edward W......Boston, Mass.
Howe, M. G..........Houston, Tex.
Hoxie, Richard L.....Portland, Me.
Hoyt, J. T. N........New York City.
Hunt, Chas. Warren..New York City.
Hutton, Wm. R.....New York City.

Johnson, Wallace C.
Niagara Falls, N. Y.
Jones, Washington.Philadelphia, Pa.
Just, George A.......New York City.

Kastl, Alex. E...Northborough, Mass.
Keefer, T. C.........Ottawa, Canada.
Kennedy, John....Montreal, Canada.
Kimball, G. A..........Boston, Mass.
King, Paul S.........New York City.
Kingsley, Marvin W.,
Cleveland, Ohio.
Knap, Jos. M........New York City.
Kuichling, E........Rochester, N. Y.

Landon, E. A........ .Groton, N. Y.
Lesley, Robt. W... Philadelphia, Pa.
Lincoln, W. S........ St. Louis, Mo.
Lovett, T. D..........Cincinnati, O.
Lundie, John...........Chicago, Ill.

Manley, Henry........Boston, Mass.
Marindin, H. L...Washington, D. C.
Martin, C. C........Brooklyn, N. Y.
Marr, G. A.........Houghton, Mich.
Mayer, Joseph.......New York City.

McCann, Thos. H....Hoboken, N. J.
McComb, D. E ...Washington, D. C.
McGuire, J. C........New York City.
McKim, Alex. Rice...New York City.
McLain, Louis R. St. Augustine, Fla.
McVean, J. J...Grand Rapids, Mich.
Melvin, David N..Linoleumville, Staten Island, N. Y.
Mesereau, C. V. ......St. Louis, Mo.
Metcalf, Wm......... Pittsburg, Pa.
Miller, Hiram A ..... Clinton, Mass.
Montfort, R ....Louisville, Ky.
Moore, Robt..........St. Louis, Mo.
Mordecai, Aug......Cleveland, Ohio.
Morison, G. S.......... Chicago, Ill.
Morley, Fred..... ...Lafayette, Ind.
Morris, Gouverneur...Detroit, Mich.

Neumeyer, Robert E..Bethlehem, Pa.
North, Edward P.... New York City.

Ockerson, John A.... St. Louis, Mo.
O'Rourke, John F....New York City.
Osborn, Frank C....Cleveland, Ohio.
Ostrander, J. E......Moscow, Idaho.
Owen, James..........Newark, N. J.

Pegram, Geo. H ....Omaha, Neb.
Perrilliat, Arsene...New Orleans, La.
Peterson, P. Alex..Montreal, Canada.
Polk, W. A.......... New York City.
Purdon, C. D..........Topeka, Kan.

Quinlan, Geo. A...... Houston, Tex.

Rafter, Geo. W.....Rochester, N. Y.
Ramsey, Jos., Jr......St. Louis, Mo.
Reece, Benjamin........Chicago, Ill.
Reed, Wm. Boardman.New York City.
Reichman, Albert .. . Chicago, Ill.
Richardson, Henry B., New Orleans, La.
Richardson, T. F.....Clinton, Mass.
Ricketts, Palmer C......Troy, N. Y.
Russell, S. Bent... ...St. Louis, Mo.

Schaub, J. W.....Hamilton, Canada.
Schuyler, James D..Los Angeles, Cal.
Scott, Addison M..Charleston, W. Va.
Seaman, Henry B....New York City.
Shaler, Ira A.. ......New York City.
Shedd, J. Herbert..Providence, R. I.
Skinner, Frank W... New York City.
Smith, Oberlin......Bridgeton, N. J.
Snow, J. P............ Boston, Mass.
Starling, Wm.......Greenville, Miss.
Stauffer, D. McN.....New York City.
Stearns, Frederic P.... Boston, Mass.
Stern, E. W........... St. Louis, Mo.
Steward, Herbert.....New York City.
Strickler, G. B.......New York City.

Taber, George A..... New York City.
Thompson, Gaylord.Rochester, N. Y.
Thomson, G. H......New York City.
Thomson, John .. . New York City.
Tinkham, Samuel E...Boston, Mass.
Tratman, E. E. Russell..Chicago, Ill.
Trautwine, John C., Jr., Philadelphia, Pa.

Van Horne, John G..New York City.
Van Sant, R. L........St. Louis, Mo.

Wallberg, E. A....Montreal, Canada.
Whittemore, D. J...Milwaukee, Wis.
Wilson, G. L....Minneapolis, Minn.
Wilson, Jos. M ... Philadelphia, Pa.
Winfree, P. B......... Bradford, Pa.
Wisner, Geo. Y....... Detroit, Mich.
Woods, Henry D.West Newton, Mass.
Worcester, J. R....... Boston, Mass.

Zabriski, A. J........New York City.

The total attendance at the Convention was as follows:

Members of the Society in all grades........................	168
Guests, including ladies..	158
Total........................	326

This statement relates only to those who registered. There were also many who attended the sessions of the Convention but failed to register, as well as many ladies and other guests who took part in the excursions and reception.

ANNOUNCEMENTS.

NEW SOCIETY HOUSE.

Some time ago, on a postal card notice of the meeting to be held June 2d, 1897, it was stated that this might be the last held in the Twenty-third Street House. At the time it appeared probable that the New House could be completed by the first of September, and it was felt that it would be an advantage to begin the season of 1897-98 in the new quarters. The building has, however, been delayed by several mechanics' strikes, and it will not be possible to finish it by that date. The Board of Direction has decided to open the House in a formal manner as soon as it can be done, and notice will be given sufficiently in advance to enable non-resident members to be present.

NEW SOCIETY HOUSE FUND.

During the past year the following additional subscriptions have been received:

Bassett, G. B. . (additional)	$50 00
Bensel, J. A.	100 00
Clarke, Thos. C. . . . . (additional)	100 00
Corti, Joseph J.	20 00
Frye, Albert I.	5 00
Gormly, W. B.	5 00
Greene, G. S., Jr.	110 00
Hollingsworth, C. H.	$50 00
Keefer, Thomas C.	500 00
Macdonald, Chas.	100 00
Molitor, F. A.	25 00
Schuyler, James D.	25 00
	$1,090 00

Total subscription to date	$20,050 00
" " paid to date	18,960 00
Profit on sale of 181 copies Historical Sketch	593 06
Unpaid subscriptions to Historical Sketch	230 00

LIBRARY.

In the list of additions to the library will be found the titles of about 400 books received from the professional library of the late Past-President William E. Worthen, who had given directions to his executors that all books therein which the Society cared to have should be given to it. A number of these volumes are valuable and rare, and the bequest, which shows Mr. Worthen's attachment to the Society, as well as his appreciation of the value of its library, seems to call for more than the usual acknowledgment, and to emphasize the fact that the growth of the Society Library is dependent principally on the thoughtful generosity of its members.

MEETINGS.

Wednesday, September 1st, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by John Findley Wallace, M. Am. Soc. C. E., entitled "The Lake Front Improvements of the Illinois Central Railroad in Chicago," will be presented. It is printed in this number of *Proceedings.*

Wednesday, September 15th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by J. L. Van Ornum, Assoc. M. Am. Soc. C. E., entitled "Theory and Practice of Special Assessments," will be printed. It is printed in this number of *Proceedings.*

Wednesday, October 6th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by J. P. Frizell, M. Am. Soc. C. E., entitled "Pressure Resulting from Changes of Velocity of Water in Pipes," will be presented. It is printed in this number of *Proceedings.*

DISCUSSIONS.

Discussions on the three papers presented at the Twenty-ninth Annual Convention, June 30th, 1897, and printed in *Proceedings* for May, 1897, will be closed October 1st, 1897. These papers were the following: "The Relation of Tensile Strength to Composition in Structural Steel," by A. C. Cunningham, M. Am. Soc. C. E.; "Recent Tests of Bridge Members," by J. E. Greiner, M. Am. Soc. C. E., and "The Power Plant, Pipe Line and Dam of the Pioneer Electric Power Company at Ogden, Utah," by Henry Goldmark, M. Am. Soc. C. E.

LIST OF MEMBERS.

ADDITIONS.

HONORARY MEMBERS.		Date of Membership.
Baker, Sir Benjamin	2 Queen Square Place, Queen Anne's Mansions, Westminster, S. W., London, England	May 5, 1897
Davidson, George	San Francisco, Cal.	May 5, 1897

MEMBERS.		
Carroll, Eugene	Res. Eng. and Supt., Butte City Water Co., Butte, Montana.	June 2, 1897

LANGE, GUNARDO AUFIN	Calle Paraguay 2231, Buenos Ayres, Argentine Republic	Mar. 3, 1897
LEISEN, THEODORE ALFRED	Chf. Eng. of Parks, Wilmington, Del.	June 2, 1897
LOFLAND, HENRY FIDDEMAN	Asst. Eng. of Erection, Edge Moor Bridge Works, Box 523, Wilmington, Del.	June 2, 1897
NOBLE, THERON AGUSTUS	Chf. Eng., Seattle Power Co., Seattle, Wash	June 2, 1897
RIX, EDWARD AUSTIN	11-13 First St., San Francisco, Cal	April 7, 1897
SCHERMERHORN, LOUIS YOUNGLOVE	Prest. Am. Dredging Co., 236 Walnut St., Philadelphia, Pa	May 5, 1897
SIBERT, WILLIAM LUTHER	823 Centre St., Little Rock, Ark	June 2, 1897
SLOCUM, CHARLES MILLS	City Eng., Springfield, Mass	May 5, 1897

ASSOCIATE MEMBERS.

FISHER, ELSTNER	Asst. Supt., M. C. R. R., Jackson, Mich.	June 2, 1897
HEDRICK, IRA GRANT	Eng. in charge of Designing, Office of J. A. L. Waddell, Kansas City, Mo.	June 2, 1897
MINER, CHARLES AUGUSTINE	U. S. Asst. Eng., Neptune, La	April 7, 1897
NEUMEYER, ROBERT ENGLER	Borough Eng. South Bethlehem, and Borough Eng. and Water Supt. of Bethlehem, Pa	Mar. 3, 1897
WALKER, JOHN SHAW	Adelaide Villa, 21 Croydon St., Petersham, Sydney, N. S. W., Australia	Mar. 3, 1897

ASSOCIATE.

POLK, WILLIAM ANDERSON	Care of Engineers' Club, 374 Fifth Ave., New York City	May 4, 1897

JUNIORS.

Swindells, Joseph Springer	560 Kosciusko St., Brooklyn, N. Y.	Feb. 2, 1897
Thompson, Robert Andrew	Inspector of Tracklaying, K. C., P. & G. Ry., Lake Charles, La.	April 6, 1897
Ward, Charles Royce	43 East 128th St., New York City	Dec. 1, 1896

CHANGES AND CORRECTIONS.

MEMBERS.

Adams, Arthur Lincoln	1530 Pacific Ave., Alameda, Cal.
Andrews, Daniel Marshall	Lincoln, Ala.
Auchincloss, William S	Box 216, Atlantic Highlands, N. J.
Bolton, Channing Moore	Rio, Albemarle Co., Va.
Booth, Wm. Henry	19 Chatsworth Rd., West Norwood, London, S. E., England.
Butterfield, Francis Eares	San Fernando, Estado de Durango, *via* Tamazula, Mexico.
Cattell, William Ashburner	26 Court Street, Brooklyn, N. Y.
Collingwood, Francis	Avon-by-the-Sea, N. J.
Davies, John Vipond	Room 579, 32 Nassau St., New York City.
Fairleigh, James Andrew	Civil Eng., Room 39, Am. Natl. Bank Bldg., Louisville, Ky.
Flagg, Josiah Foster	Care of Morris Lindsay, Tenafly, N. J.
Frye, Albert Irwin	52 Pinckney St., Boston, Mass.
Gamble, Francis Clarke	Nelson, B. C., Canada.
Goldmark, Henry	39 Cortlandt St., New York City.
Grimm, Carl Robert	500 Union Place, Elmira, N. Y.
Hazlehurst, George Blagden	808 Fidelity Bldg., Baltimore, Md.
Hislop, John	Lamar, Prowers Co., Colo.
Hodges, Arthur	23 Kenwood Ave., Newton Centre, Mass.
Hoxie, Richard Leveridge	Maj., Corps of Engrs., U. S. A., P. O. Box 1671, Portland, Me.
Jewett, William Cornell	Sub-Station No. 2, Cleveland, Ohio.
King, Paul Sourin	Chf. Eng., The Wilson & Baillie Mfg. Co., 85 Ninth St., Brooklyn, N. Y.
Lowrie, Harvey Childs	753 Equitable Bldg., Denver, Colo.
McMinn, Thomas James	100 William St , New York City.
Maltby, Frank Bierce	U. S. Asst. Eng., Osage City, Mo.
Mills, James Ellison	San Fernando, Estado de Durango, *via* Tamazula, Mexico.
Morley, Fred	Lapeer, Mich.

NEILSON, CHARLES....................Rooms 50 and 52 Atlantic Bldg., Washington, D. C.
NOYES, ELLIS BRADFORD................409 Middle St., Portsmouth, Va.
RAYMOND, CHARLES WARD..............Care of Henry Lahiff, Placerville, Cal.
SIMS, ALFRED VARLEY.................Wenonda, Va.
SKINNER, FRANK W....................Editorial staff, *Engineering Record*, 100 William St., New York City.
STAUFFER, DAVID MCNEELY.............Editor *Engineering News*, St. Paul Bldg., 220 Broadway, New York City.
STUART, ALFRED ALLEN................Chf. Eng. The Degnon McLean Const. Co., 1 Broadway, New York City.
THACHER, EDWIN.......................National Hotel, Topeka, Kan.
THOMPSON, BENJAMIN..................Asst. Eng. Southern Ry. Norfolk, Va.
TOWLE, STEPHENSON...................Cons. Eng., 220 Broadway, New York City.
TREADWELL, LEE.......................225 Woodward Ave., Kalamazoo, Mich.
WADDELL, J. A. L......................60-64 Gibraltar Bldg., Kansas City, Mo.
WALLACE, JOHN FINDLEY...............Vice-Prest. and Gen. Mgr. Mathieson Alkali Works, Saltville, Va.
WHINERY, SAMUEL.....................Vice Prest. Warren-Scharf Asphalt Paving Co., 81 Fulton St., New York City.
WHITFORD, OSCAR F....................356 Maryland St., Buffalo, N. Y.
WILGUS, WILLIAM JOHN................Res. Eng. Eastern Div. N. Y. C. & H. R. R. R. & Leased Lines, Grand Central Station, New York City.

ASSOCIATE MEMBERS.

BASCOME, WESTERN RADFORD.......... New East River Bridge, 84 Broadway, Brooklyn, N. Y.
BROWNELL, ERNEST H.................Care Col. Wm. Ludlow, Army Bldg., New York City.
COHEN, FREDERICK WILLIAM............Care The Pa. Steel Co., Steelton, Pa.
DESPARD, DUNCAN LEE.................1035 St. Paul St., Baltimore, Md.
FOLWELL, AMORY PRESCOTT.............Glens Falls, N. Y.
GREENE, CARLETON....................Care George S. Greene, Jr., Dept. of Docks, Pier A, North River, New York City.
HARDY, HARRY........................19 Brayhorke Terrace, Hastings, Sussex, England.
HARTS, WILLIAM WRIGHT...............1st Lieut. Corps of Engrs., U. S. A., High Bridge, Ky.
HAYES, GEORGE SAMUEL................1123 Broadway, New York City.
HENRY, PHILIP WALTER................Gen. Mgr. The Barber Asphalt Paving Co., 11 Broadway, New York City.

HILL, JOHN EDWARD....................59 Paterson St., New Brunswick, N. J.
HOUSTON, JOHN JAY LAFAYETTE..........3707 Locust St., Philadelphia, Pa.
JOHNSON, ALBERT LINCOLN..............606 Century Bldg., St. Louis, Mo.
KIRKPATRICK, WALTER GILL.............West Point, Miss.
KNOWLES, MORRIS......................Res. Engr. Filtration Commission, Pittsburg, Pa.
LUDWIG, JULIUS ALFRED................Care The Osborn Co., Osborn Bldg., Cleveland, Ohio.
McKENZIE, THOMAS.....................Box 712, Westerly, R. I.
MITCHELL, EDWIN......................6 East Lexington St., Baltimore, Md.
MONCURE, WILLIAM AUGUSTUS........... Chf. Engr.'s Office, P. R. R., Philadelphia, Pa.
OSTRANDER, JOHN EDWIN................Prof. Mathematics and Civil Engineering, Mass. Agric. College, Amherst, Mass.
ROSENBERG, FRIEDRICH.................17 South Hawk St., Albany, N. Y.
STENGER, ERNEST......................812 North 39th St., Omaha, Neb.
STEVENS, ALEXANDER...................157 East 67th St., New York City.
VAN ORNUM, JOHN LANE.................Russell House, Humboldt, Iowa.
WASHINGTON, WILLIAM DE HERTBURNE...1 Broadway, New York City.
WERNER, EMRICK ADOLPH................Care Variety Iron Works Co., Cleveland, O.
WILLIAMS, GARDNER STEWART............57 E. Hancock Ave., Detroit, Mich.

ASSOCIATES.

COMER, HARRY.........................Supt. Lehigh Valley Creosoting Co., 1206 Bowling Green Bldg., 11 Broadway, New York City.
DAVIS, JOB WOODBRIDGE................523 West 173d St., New York City.
GIBSON, WILLIAM, Jr..................167 Gates Ave., Brooklyn, N. Y.
LINDENBERGER, CASSIUS HOWARD.........Wayne Hotel, Detroit, Mich.
MILNE, PETER.........................1241 Dean St., Brooklyn, N. Y.

JUNIORS.

ANDERSON, JAMES CHRIS................Engr. and Supt. The Varley Duplex Magnet Co., 138 Seventh St., Res. 516 Summit Ave., Jersey City, N. J.
BARNEY, PERCY CANFIELD...............Dept. C. & R., U. S. Navy Yard, Washington, D. C.
BEARD, ELMER HARRY...................Asst. City Engr., Reading, Pa.
BEHRMAN, GEORGE WILLIAM..............39 Cortlandt St., New York City.
BRUSH, WILLIAM WHITLOCK............. 549 Jefferson Ave., Brooklyn, N. Y.
CRANE, WILL. EDWIN...................Box 8, North Tarrytown, N. Y.
DIEBITSCH, EMIL......................177 Schermerhorn St., Brooklyn, N. Y.

FAY, FREDERIC HAROLD..................City Engr.'s Office, 60 City Hall, Boston, Mass.
FORD, WILLIAM HAYDEN................86 Carroll Place, New Brunswick, N. J.
GREEN, HOWARD BURKHARDT............434 Guaranty Bldg., Buffalo, N. Y.
HURTIG, JULIUS BERNSTEIN.............12 East 97th St., New York City.
IVES, ARTHUR STANLEY....................Expert for Steel and Iron Construction, Bldg. Dept., City Hall, Brooklyn, N. Y.
JACKSON, WILLIAM.......................465 Wilson Ave., Cleveland, Ohio.
KINSEY, FRANK WILMARTH..............Box 207, New Castle, Del.
MILLARD, CURTISS.......................Supt. and Engr. The St. L. C. & St. P. R'y Co., 212 North 5th St., Springfield, Ill.
MOISSEIFF, LEON S......................Dutton Lock Co., 11 Broadway, New York City.
OESTREICH, HENRY LEWIS, Jr...........2092 Bathgate Ave., Tremont New York City.
PHILLIPS, HOWARD CRATHORNE......... Millbrook, N. Y.
RAYMOND, COLES ABEL.....................1233 Miami St., Toledo, Ohio.
REYNOLDS, JUSTIN OAKLEY............ Jonesport, Washington Co., Maine.
RICHARDS, JERRE TURNER...............314 South Boulevard, Oak Park, Ill.
STEVENS, PERLEY EGBERT..............202-211 S. W. Washington, D. C.
STRICKLER, GRATZ BROWN..............Ocean City, Md.
TAPPAN, ROGER.............................Hawthorne Inn, East Gloucester, Mass.
WALLBERG, EMIL ANDREW...............69 Imperial Bldg., Montreal, Canada.
WALLS, WALTER SCOTT ....102 Mansfield St., Montreal, P. Q., Canada.
WULFF, ADOLPH GEORGE................614 Johnston Bldg., Cincinnati, Ohio.

FELLOW.

MEYER, HENRY CODDINGTON............100 William St., New York City.

DEATHS.

BRUSH, CHARLES BENJAMIN............ .Elected Associate, Sept. 6th, 1871; Member, Sept. 5th, 1877; Director, 1888-1891; Vice-Prest., Jan. 20th, 1892, to Jan. 17th, 1894; died June 3d, 1897.
SICARD, MIRTILIANO ....Elected Member Jan. 4th, 1882; died March 17th, 1896.

ADDITIONS TO

LIBRARY AND MUSEUM.

From American Institute of Electrical Engineers, New York, N. Y.:
Transactions, Vol. XIII., 1896.

From American Institute of Mining Engineers, New York, N. Y.:
Advance papers as follows:
American Magnesite; A Modern Silver-Lead Smelting Plant; An Improved Assay-Muffle; Brief Note on Rail Specifications; Notes on the Determination of Insoluble Phosphorus in Iron Ores; Notes on the Northern Black Hills of South Dakota; Sorting before Sizing; The Cement Materials of Southwest Arkansas; The Chromite Deposits on Port au Port Bay, Newfoundland; The Enterprise Mine, Rico, Colorado; The Handling of Material at the Blast-Furnace; The Hardening of Steel; The Invention of the Bessemer Process; The Occurrence of Gold Ores in the Rainy River District, Ontario, Canada; The Quality of the Boiler-Water Supply of a Portion of Northern Illinois.
Transactions, Vol. XXVI, 1896.

From American Iron and Steel Association, Philadelphia, Pa.:
Annual Report of Statistics of the American and Foreign Iron Trades for 1896.

From Association of Engineers and Architects of Mexico, Mexico:
Anales, Tomo V, 1896.

From W. S. Auchincloss, Bryn Mawr, Pa.:
Waters within the Earth, and Laws of Rainflow.

From C. Baillairgé, Quebec, Can.:
Technical Education of the People in Untechnical Language.
Hudson Bay: A New Colony. A Railway to reach it.
Bribery and Boodling, Fraud, Hypocrisy and Humbug, Professional Charges and Pecuniary Ethics
Address of Welcome to the Montreal Section of Canadian Architects.
The Stereometricon.
Papers read before the Royal Society of Canada, 1882 and 1883.
Le Communisme.
La Ventilation Libre des Egouts en Rapport avec l'Hygiene de l'Habitation.
Biographie de Charles Baillairgé.
Homonymes Français.
English Homonyms.
Transactions of the Geographical Society of Quebec, 1893 to 1897.

From Wm. J. Baldwin, New York, N. Y.:
Steam Heating Data.

From Onward Bates, Chicago, Ill.:
Minutes of Convention of Employés of Bridge and Building Department, Chicago, Milwaukee and St. Paul Railway, January 20th and 21st, 1897.

From G. H. Benzenberg, Milwaukee, Wis.:
Annual Report of the Board of Public Works for the year ending December 31st, 1896.

From W. M. Black, Washington, D. C.:
Official Army Register for 1897.

From Board of Trustees of the Sanitary District of Chicago, Chicago, Ill.:
Proceedings April 7, 14, 16, 21 and 28; May 5, 12, 19 and 26; June 2, 9, 23 and 30; 1897.

From Boston Public Library, Boston, Mass.:
A List of Periodicals, Newspapers, Transactions and other Serial Publications Currently Received in the Principal Libraries of Boston and Vicinity.

From R. R. Bowker, New York, N. Y.:
Reprint of the Appendix of the American Catalogue, 1890-95. Publications of Societies, July 1, 1890; June 30, 1895.

From Clifford Buxton, Toledo, O.:
Proceedings of the Michigan Association of Surveyors and Civil Engineers, January 10-12, 1882; January 1-4, 1884.
Proceedings of the Michigan Engineering Society, February 17-20, 1885; January 26-28, 1886, and January 25-27, 1887; January 17-20, 1888, 1889, 1890, 1891.
Proceedings of the Connecticut Association of Civil Engineers and Surveyors. First Annual Meeting January 13, 1885; Sixth Annual Meeting January 14, 1890; Seventh Regular Meeting September 25, 1885.
The Technic, the Annual of the Engineering Society of the University of Michigan, 1889, 1890, 1891.
Proceedings of the Association of County Surveyors and Civil Engineers of the State of Indiana for 1882, 1883, 1884, 1885, 1886.
Proceedings of the Indiana Society of Civil Engineers and Surveyors of the State of Indiana for 1888, 1889-90, 1891.
Proceedings of the Association of Provincial Land Surveyors of Ontario for 1886, 1887, 1888, 1889, 1890, 1891.
Proceedings of the Association of Dominion Land Surveyors for 1888, 1890, 1891.
Report of the Annual Meetings of the Illinois Society of Engineers and Surveyors for 1886, 1887, 1888, 1889, 1890, 1891.
Proceedings of the Second and Third Annual Conventions of the Iowa Society of Civil Engineers and Surveyors, 1889, 1890.
Proceedings of the Fourth and Fifth Annual Meetings of the Iowa Surveyors' and Civil Engineers' Association, 1887, 1889.

Proceedings of the Missouri Association of Surveyors and Civil Engineers for 1885, 1886.
Transactions of the Arkansas Society of Engineers, Architects and Surveyors, Vol. III, November, 1889.
Engineering Association of the South. Publication No. 1. November 21, 1889, to November 15, 1890.

From California State Mining Bureau, Sacramento, Cal.:
Mineral Productions for 1896.

From Canadian Institute, Toronto, Can.:
Proceedings, May, 1897.
Transactions, October, 1896.

From O. M. Carter, Savannah, Ga.:
The Influence of Sea Water on Hydraulic Mortars.

From Albert Cushing Crehore, Hanover, N. H., and George Owen Squier, Fortress Monroe, Va.:
The Synchronograph. A New Method of Rapidly Transmitting Intelligence by the Alternating Current.

From W. Bell Dawson, Ottawa, Can.:
Survey of Tides and Currents in Canadian Waters.

From Delaware College, Newark, Del.:
Catalogue and Announcements, 1897.

From Department of Mines, Pretoria, S. A. R.:
Vergelijkende Staat van de Opbrengst der Publieke Delverijen in de Zuid Afrik Republiek over het eerste Kwartaal 1896 en 1897.

From Director General of Railways, Simla, India:
Administration Report on the Railways in India for 1896-97.

From Dyckerhoff & Söhne, Amöneburg, Germany:
Protokoll der Verhandlungen des Vereins Deutscher Portland Cement Fabrikanten am 24 und 25 Februar, 1897.

From Engineering News Publishing Co., New York, N. Y.:
Bureau of the American Republics. Bulletins on Haiti, Venezuela, Uruguay, Guatemala, Colombia, Costa Rica, Bolivia, Foreign Commerce.
Proceedings Central Railway Club 1894-96. 16 numbers.
Proceedings Western Railway Club 1894-97. 17 numbers.
Papers read before the Engineering Society of the School of Practical Science, Toronto, Can., Nos. 6, 7, 8.
Transactions of the Association of Engineers of Cornell University, 1894, 1896.
Fourteenth Annual Report of the Ohio Society of Surveyors and Civil Engineers, January, 1894.
Twelfth, Fourteenth and Fifteenth Annual Reports of the Indiana Engineering Society, 1892, 1894-95.
Transactions of the Denver Society of Civil Engineers and Architects, No. 1. 1890.
Proceedings of Engineers' Society of Western Pennsylvania, Vol. VII, VIII.
Proceedings of the Iowa Society of Civil Engineers and Surveyors, 1893, 1894, 1895, 1896.
The Michigan Engineers' Annual, 1892, 1893, 1894, 1895, 1896.
Proceedings of Southern and Southwestern Railway Club, 1893-96. 9 numbers.
Proceedings of the New England Railroad Club, 1894-96. 7 numbers.
Proceedings of the New York Railroad Club, 1893-96. 19 numbers.
Proceedings of the Western Railway Club. 1893-94 7 numbers.
Proceedings of the Connecticut Association of Civil Engineers and Surveyors. 1885-1896. 11 numbers.
The Transit. Vol. IV, No. 1, June, 1896.
Hand Book of the American Republics, 1893.
Geological Survey of Kentucky, three parts.
Report on Condition of the Jamaica Railway Extension.
Maps to accompany Report of Secretary of Internal Affairs of Pennsylvania on Boundaries of the Commonwealth, 1887.

From Leon Francq, Paris, France:
Sur la Traction Mécanique dans Paris. Extrait du Bulletin de la Société Internationale des Electriciens.

From J. P. Frizell, Boston, Mass.:
An Inquiry as to a More Perfect Form of Water-Wheel.

From J. B. Henderson, Brisbane, Australia:
Report of the Hydraulic Engineer on Water Supply of Brisbane, Australia.

From Gus. C. Henning, New York, N. Y.:
Congrès de l'Association Internationale pour l'Essai des Matériaux. Programmes, Circulars, Statuts de l'Association, etc.

From A. E. Hunt, Pittsburgh, Pa.:
Aluminum.

From Illinois Society of Engineers and Surveyors, Peoria, Ill.:
Twelfth Annual Report, January, 1897.

From Institution of Civil Engineers, London, Eng.:
Minutes of Proceedings, Vol. CXXVIII.
Report of the Council, Session 1896-97.
List of Members, June 3, 1897.

From J. S. Keerl, Helena, Mont.:
The Standing of Engineering among the Professions.

From M. W. Kingsley, Cleveland, Ohio:
Forty-first Annual Report of the Water Works Division of the Department of Public Works of the City of Cleveland, O., for the year ending December 31st, 1896.

From Arthur Koppel, New York, N. Y.:
Industrie-Bahnen.

From E. Kuichling, Rochester, N. Y.:
Twenty-first Annual Report of the Executive Board of the City of Rochester, N. Y., for 1896.

From J. B. Lippincott Company, Philadelphia, Pa.:
The Railway Builder. A Handbook for Estimating the Cost of American Railway Construction and Equipment.

From McCormick Harvesting Machine Co., Chicago, Ill.:
Who Invented the Reaper?

From John M. Moncrieff, London, Eng.:
The Design and Construction of Dock Gates of Iron and Steel.
The Standardizing of Working Loads and Working Stresses for Railway Bridges.
The Redheugh Bridge. Extract from the *Engineer*.
Theoretical and Practical Notes on Beams, Columns and Roof Trusses.

From G. S. Morison, Chicago, Ill.:
The Civil Engineer and the University.

From W. F. Morse, New York, N. Y.:
Cremation, Disinfection, Sterilization.

From Munn & Co., New York, N. Y.:
Scientific American Supplement Reference Catalogue.

From William Murdoch, Saint John, N. B.:
Engineer and Superintendent's Report on Sewerage and Water Supply, 1896.

From J. A. Ockerson, St. Louis, Mo.:
Map of the Lower Mississippi River from the Mouth of the Ohio River to the Head of the Passes.

From F. L. Ortt, Hague, Holland:
The Effect of Wind and Atmospheric Pressure on the Tides.

From Wm. Barclay Parsons, New York, N. Y.:
Routes and General Plan of Board of Rapid Transit Railroad Commissioners, adopted by Resolution, February 4th and April 1st, 1897.

From Patent Office, London, Eng.:
Abridgments of Specifications of Patents for Inventions; Steam Generators; Waterproof and Similar Fabrics; Washing and Cleaning Clothes; Domestic Articles and Buildings; Moulding Plastic and Powdered Substances; Stoves, Ranges and Fireplaces; Registering, Indicating, Measuring and Calculating; Valves and Cocks.

From Ernest Pontzen, Paris, France:
Le Mécanisme du Lit Fluvial.

From Herman Poole, New York, N. Y.:
Special Karte der Eisenbahnen Mittel Europa's.

From J. B. Pope, San Bernardino, Cal.:
The Measurement of Water for Irrigation.

From Wm. G. Raymond, Troy, N. Y.:
Report on an Additional Water Supply for the City of Troy, June 18, 1897.

From Edward A. Rix, San Francisco, Cal.:
Electrical Engineering, June 15th, 1897, containing "The Use of Compressed Air for Mining Purposes."

From A. H. Sabin, New York, N. Y.:
Application of Paints, Varnishes and Enamels for the Protection of Iron and Steel Structures and Hydraulic Work.

From M. R. Sherrerd, Newark, N. J.:
Annual Reports of the Newark Aqueduct Board for 1882 to 1890, inclusive.
Annual Reports of the Board of Street and Water Commissioners of the City of Newark, N. J., for the years ended December 31st, 1892, 1893, 1894, 1895 and 1896.

From Smithsonian Institution, Washington, D. C.:
A Catalogue of Scientific and Technical Periodicals, 1665-1895.
Annual Report Showing the Operations, Expenditures and Condition of the Institution to July, 1895.

From George D. Snyder, Williamsport, Pa.:
Reports of Departments of the City of Williamsport, Pa., for the year 1896.

From Society of Engineers, London, Eng.:
Transactions for 1896, and General Index 1857 to 1896.

From State Agricultural College, Fort Collins, Colo.:
Bulletins Nos. 36, 37 and 38. Sugar Beets; Sheep Scab and a Few Enemies of the Orchard. Birds of Colorado.

From Trustees of the Public Library, Boston, Mass.:
Annual Report for 1896.

From U. S. Department of Agriculture:
Report of the Chief of the Weather Bureau 1895-96.

From U. S. Department of the Interior:
Report on Vital and Social Statistics in the United States at the Eleventh Census Part 2.
Report on Insane, Feeble-Minded, Deaf and Dumb, and Blind in the United States at the Eleventh Census.
Water Supply and Irrigation Papers of the U. S. Geological Survey. Sewage Irrigation; Irrigation near Phœnix, Ariz.

From U. S. Light-House Board:
Annual Report for the fiscal year ended June 30th, 1896.

From U. S. Patent Office:
Alphabetical Lists of Patentees and Inventions for the Quarter ending December 31st, 1896.

From U. S. War Department:
The Influence of Sea Water on Hydraulic Mortars.

From U. S. W. Department, Chief of Engineers:
Forty-six Specifications for the Improvement of Certain Rivers and Harbors.
Sixty-five Reports on the Improvement of Certain Rivers and Harbors, etc.

From U. S. War Department, Ordnance Office:
Index to Vol. III. Notes on the Construction of Ordnance.

From University of Kansas, Topeka, Kans.:
Thirty-first Annual Catalogue for the year 1896-97.

From University of the State of New York, Albany, N. Y.:
Seventy-seventh Annual Report of the New York State Library.
State Library Bulletin. Additions No. 3, September, 1894; No. 4, September, 1896.
Extension Bulletins, Nos. 14, 15, 16, 17 and 18.
Report of the State Engineer and Surveyor for the fiscal year ending September 30, 1885.

Annual Financial Report of the Auditor of the Canal Department for the fiscal year ending September 30, 1873.

From I. M. De Varona, Brooklyn, N. Y.:
Analytical Investigations made to determine the causes affecting the Quality of the Water Supply (Brooklyn, N. Y.) during the Summer of 1896.

From L. F. Vernon Harcourt, London, Eng.:
Report on the River Hugli.

From H. M. Wilson, Washington, D. C.:
Water Supply and Irrigation Papers of the U. S. Geological Survey. Pumping Water for Irrigation.

From A. H. Wood, Nashville, Tenn.:
Sixth Annual Report of the Bureau of Labor, Statistics and Mines of Tennessee, 1896.

By bequest of W. E. Worthen, New York, N. Y.:
American and European Railway Practice in the Economic Generation of Steam.
Andrew's Latin-English Lexicon.
Annual Report of the Board of Commissioners of Central Park, 1866.
Annual Report of the Board of Health, N. Y., May 1, 1873, to April 30, 1874.
Annual Reports of the Board of Health of the Health Department of the City of New York, April 10, 1871, April 30, 1874; 1891.
Annual Reports of the Department of City Works, Brooklyn, for 1889, 1890, 1891.
Annual Reports of the Metropolitan Board of Health, 1868, 1869.
Annual Reports of the State Board of Health of Massachusetts, 1870, 1871.
Appleton's Cyclopedia of Applied Mechanics, 2 vols
Appleton's Dictionary of Mechanics, 2 vols.
Appleton's Mechanics' Magazine, 1851.
Archiv für Eisenbahnwesen, 23 numbers.
Article on Street Pavements, Department of Public Works, New York, 1892.
Atlas of the City of New York, 1885.
Atlas of Staten Island, 1887.
Brick and Marble of the Middle Ages. Street, 1855
Bronx River Diversion, 3 vols.
Brooklyn City Water-Works, 1854.
Building News, 1871, Plates. 3 vols.
Cable Traction Systems of the Rapid Transit Cable Company, New York, 1889.
Carpenter's and Builder's Assistant, 1882.
Chimie Céramique, Geologie, Metallurgie. Ebelmen, 1861. 3 vols.
City Hall, Baltimore; History of Construction and Dedication, 1877.
Civil Engineering, Public Works and Architecture at Paris Universal Exposition, 1889.
Communication from the General Board of Health on Operation of Pipe Sewers, 1855.
Conferences of Charities and Corrections. 3 vols.
Construction of Mill Dams, 1874.
Contract Drawings. London Main Drainage. 6 vols.
Contract Drawings. Thames Embankment. 2 vols.
Correlation and Conservation of Forces. Youmans, 1865.
Cottage Residences and Cottage Grounds. Downing, 1856.
Cours de Mécanique Appliquée aux constructions. Deuxième Partie, Hydraulique. Collignon, 1870.
Cours de Physique de l'Ecole Polytecnique, 1868. 3 vols.
Croquis d'Architecture, 1867-1870. 2 vols.
De l'Industrie de la Papeterie. Planche, 1853.
Deviation des Sources de la Vallée de la Vanne.
Description of the Britannia Bridge over Menai Straits.
Description of the New York Croton Aqueduct by T. Schramke.
Des Machines et Appareils destinées à l'élévation des Eaux. Morin, 1863.
Dictionary of Arts, Manufactures and Mines. Ure. Vol. 1.
Dictionary of Science. Rodwell, 1871.
Dictionnaire Raisonne de l'Architecture. Le Duc, 1867. 10 vols.
Dragon Fly or Reactive Passive Locomotion.
Drawings of High Service Engine No. 5 of St. Louis Water-Works.
Drawing from Objects. Bolton, 1850.
East River Bridge. Laws and Reports, 1868-84.
Elasticity, Extensibility and Tensile Strength of Iron and Steel. Styffe, 1869.
Electric Motor. Martin, 1887.
Electricity and Magnetism. Jenkin, 1887.
Electrolysis. Fontaine, 1885.
Elements of Experimental Chemistry. Henry, 1815. 2 vols.
Elementary Treatise on Natural Philosophy. Deschanel, 1884. 3 vols.
Encyclopædia of Cottage, Farm and Villa Architecture. London.
Engineering Examples, Stations, Engine-Houses, etc.; Iron Bridges, Brick Bridges, Timber Roofs, Trussed Bridges and Viaducts; Iron Roofs. 6 parts.
Engineering Facts and Figures, 1866-1868.
Essay on the Boilers of Steam Engines. Armstrong, 1839.
Etude sur les Signaux de Chemins de Fer à Double Voie. Brame, 1867.
Examination of Water for Sanitary and Technical Purposes. Leffman and Beam, 1889.
Examples of Machine Details
Experiments on the Strength of Wrought Iron and of Chain Cables. Kent, 1879
Explosions of Steam Boilers. Robinson, 1870.
Fire Protection of Mills. Woodbury, 1882.
Fires; their Causes, Prevention and Extinction. Moore, 1882.
Formules, Tables et Reseignements Usuels; Aide Mémoire des Ingénieurs, des Architects, etc. Claudel, 1872. 2 vols.

Fundamental Ideas of Mechanics. Morin, 1860.
General Theory of Bridge Construction. Haupt.
Glasgow Water Works. Gale, 1864.
Good Roads (Periodical), 37 numbers.
Grammigraphia; or the Grammar of Drawing. Robson, 1799.
Handbook of Architectural Styles. 1876.
Handbook of Architecture. Fergusson, 1859.
Handbooks for Handicrafts. 1887-8. 3 vols.
Handbook of Sewage Utilization. Burke, 1872.
Health of Towns Commission on Supply of Water. 1844.
History of the Boston Water Works, from 1868 to 1876.
History of the First Locomotives in America. Brown, 1874.
History of the Introduction of Pure Water into the City of Boston
Illustrative Plates of the Cornish and Boulton and Watt Engines erected at the East London Water Works. Wicksteed.
International Scientific Series; Growth of the Steam Engine; Earthquakes; Animal Mechanism; New Chemistry; Microbes, Ferments and Moulds; Forms of Water; Animal Life. 7 vols.
Interoceanic Canals. Stuckle, 1870.
Iron Applied to Railway Structures. 1850.
Iron Manufacture of Great Britain. Truran, 1867.
Kinematics. MacCord, 1883.
Kinematics of Machinery. Reuleaux, 1876.
L'Exposition Universelle de 1867, Illustrée.
Liddell and Scott's Greek-English Lexicon.
Light and Electricity. Tyndall, 1871.
Machinery of the Nineteenth Century. 1856. 6 parts.
Main Drainage Works of the City of Boston. Clarke, 1885.
Malleable Iron Bridges. Dempsey, 1850.
Manual of Power for Machines, Shafts and Belts. Webber, 1879.
Manuel Pratique du Chauffage et de la Ventilation. Morin, 1867.
Map of the City of Brooklyn (mounted).
Map of the Profile and Route of the New Aqueduct. Sections 12, 13, 14.
Mathematical Principles of Natural Philosophy. Newton, 1848
Meigs Elevated Railway System. 1887.
Mémoire sur les Reservoirs de Gentilly.
Memoranda on the Strength of Materials used in Construction. Whildin, 1867.
Methods of Preserving Timber in Situations which Expose it to Decay.
Metropolitan Board of Works; London Main Drainage Specifications, 3 vols.
Thames Embankment Specifications. 2 vols.
Naval Architecture. Russell. 3 vols.
Naval Dry Docks of the United States. Stuart, 1852.
Notice of a Flood at Frastanz, in the Vorarlberg, in the Autumn of 1846.
Notice sur l'Appareil d'Induction Electrique de Ruhmkorff. Du Monel, 1867.
On Heat and its Relations to Water, and Steam Williams, 1860.
On the Strength of Cast-Iron Pillars. Francis, 1865.
On the Supply of Water to the Lancashire and Yorkshire Towns.
On the Supply of Water to London from the Sources of the River Severn, 1865.
On the Water Supply of Edinburgh, 1863.
Papers and Reports of the American Public Health Association. 19 vols.
Parliamentary Reports:
—from the Select Committee on Railways, with Index, 1881. 2 vols.
—of Select Committee on Metropolis Water Bills, 1852.
—of the Royal Commission on Water Supply, 1869. 2 vols.
—from the Select Committee on Ordinance, 1863.
—of the Commissioners appointed to inquire into the Application of Iron to Railway Structures, 1849. 2 vols.
—from the Select Committee on Lighting by Electricity, 1879.
—of the Metropolitan Commission of Sewers, 1853.
Petrolia; its History and Development. Cone, 1870.
Physical Geography of the Sea. Maury, 1857.
Plan of New York City from the Battery to Spuyten Duyvil Creek, 1867.
Popular Lectures on Scientific Subjects. Helmholtz, 1881.
Practical Treatise of Railroads and Carriages. Tredgold, 1825.
Pratique de l' Art de Construire; Maconnerie, Terrasse et Plâtrerie. Claudel, 1870.
Principles of Geology. Lyall, 1859
Principles of Gothic Ecclesiastical Architecture. Bloxam, 1859.
Preliminary Map of the Lower Mississippi River. Miss. River Commission, 1885.
Principles, Processes and Effects of Draining Land French, 1884.
Proceedings of the American Association for the Advancement of Science, 1887-1897.
Proceedings of the Association of Municipal and Sanitary Engineers and Surveyors, 1873-1882. 7 vols.
Proportions of the Human Figure. Bonomi, 1880.
Railway Appliances Barry, 1890.
Railway Economy. Le Chatelier, 1869.
Railway Machinery. Clark, 1855. 2 vols.
Real Estate on the Business Line of Broadway as Affected by Lack of Rapid Transit, 1884.
Recherches Experimentales relatives au Mouvement de l'Eau dans les Tuyaux. Darcy, 1857.
Regular Proposals, City of Brooklyn, Division of Water Supply, 1895.
Reports of Artisans on the Paris Universal Exhibition, 1867.
Reports of Experiments on the Properties of Metals for Cannon. T. J. Rodman.

Report of the Board of Health, Brooklyn, 1875-76.
Report of the Board of Rapid Transit Railroad Commissioners in and for the City of New York, October 20th, 1891.
Report of the Commissioner of City Works of Brooklyn, N. Y., 1895.
Report of the General Board of Health on the Supply of Water for the Metropolis (London) with Appendixes, 1850. 5 vols.
Report of the Rapid Transit Commission to the Massachusetts Legislature, 1892
Reports of St. Louis Water-Works, 1866 to 1876.
Report of the Sewerage of the District of Columbia, 1890
Report of the State Board of Health of Tennessee, 1880-1884.
Report of the United States Board appointed to test Iron, Steel and other Metals, 1878.
Reports of the United States Commissioners to the Paris Universal Exposition, 1878. 5 vols
Reports of the United States Commissioners to the Universal Exposition of 1889. 5 vols.
Reports of the Water Engineer of Liverpool, 1865, 1873.
Report of the Water-Works Committee of Dublin, June 3d, 1864.
Report of the West End Street Railway of Boston.
Reports on the Edinburgh and Districts Water Supply, 1869.
Report on Future Extension of Water Supply of the City of Brooklyn. 1896.
Report on Filtration of River Waters. Kirkwood
Report of Montreal Harbor. 1877.
Report on the last two Cholera Epidemics of London as affected by the Consumption of Impure Water. 1856.
Report on the Sanitary Condition of Edinburgh. 1865.
Report on the Sewerage of the Mystic and Charles River Valleys. 1889.
Reports on the Water Supply of Glasgow. 1872, 1873.
Report upon the Flowage of Meadows of Concord and Sudbury Rivers. 1860
Report upon the Sanitary Condition of New York. 1866.
Report upon the Water-Power of Maine Wells 1868.
Rudimentary Treatise on Steam Boilers; Clocks, Watches and Bells; Blasting and Quarrying Stone; Art of Building; Construction of Locks; Marine Engine; Foundations and Concrete Works; Elements of Practical Mechanism, Civil Engineering; Road Making; Iron Girder Bridges; Construction of Lighthouses; Railways; Dictionary of Terms used in Civil and Naval Architecture; Construction of Cranes and Machinery; Carpentry and Joinery of Roofs; Navigation; Law of Contracts; Masonry and Stonecutting; Erection of Dwelling Houses; Drainage and Sewage of Towers and Buildings; Anthracite and Health; Gas Works; Waterworks for the Supply of Cities and Towns; On the Use of Field Artillery; Steam and Locomotion; Electricity; Natural Philosophy, 33 vols.
Rusting of Iron and Steel.
Scheme for the Supply of Water to the Towns of Sheffield, Rotherham-cum-Kimberworth and Doncaster, 1866.
Science of Mechanics. Mach, 1893.
Scientific Theism. Abbot, 1886.
Sketch of the Civil Engineering of North America.
Sketch of the Life and Works of George W. Whistler, 1887.
Slide-Valve practically explained. Rose, 1890.
State of Prisons and of Child Saving Institutions in the Civilized World. Wines.
Statistics and Water Rates. National Meter Co., 1887.
Storage of Water. Denton, 1874.
Strata Map of the United States (framed).
Suggestions as to the Selections of Sources for Water Supply. Stearns, 1890.
Supply of Water to Towns. Latham, 1865.
Théorie Mécanique de la Chaleur. Briót, 1869.
Topographical Map of the Croton Water-Shed (mounted).
Traité d' Assainissement Industriel. De Freycinet, 1870.
Traité de l' Application des Fer de la Fonte et de la Tole dans les Constructions Civils, 1841.
Traité de la Chaleur. E. Peclet, 1861. 2 vols
Traité de la Mésure des Eaux Courantes. Boileau, 1854.
Traité théorique et pratique de Têlégraphie Electrique. Du Moncel, 1864.
Transactions of the Brighton Health Congress, 1881.
Transformation de la Vidange et Suppression de la Voirie de Bondy. 1871.
Treatise on Cranes. Towne, 1883.
Treatise on Dry Rot in Timber. Britton, 1875.
Treatise on High Pressure Steam Boilers. Barr, 1880.
Treatise on Lead Diseases and on the Use of Lead Pipe. Dana, 1848.
Treatise on Mills and Millwork. Fairbairn, Part 2. 1863.
Treatise on Steam and its Application. Ward, 1860.
Treatise on the Cornish Pumping Engine. Pole, 1844.
Treatise on the Law of Navigable Rivers. Houck, 1868.
Treatise on the Law of Watercourses. Angell, 1869.
Treatise on the Law of Waters. Gould, 1891.
Treatise of the Law of Waters. Wool rich, 1851.
Treatise on Metallurgy. Overman, 1866.
Treatise on the Metallurgy of Iron Bauerman, 1868.
Treatise on Theatres. 1790.
Treatise on the Use of Belting. Cooper, 1878.

Treatise on Ventilation. Leeds, 1871.
Treatise on Warming Buildings by Hot Water. Hood, 1855.
Treatment of Sewage. Tidy, 1887.
Turning and Mechanical Manipulation. Holtzapffel, 1852. 3 vols.
Unpolluted Streams. Manners, 1858.
United States Naval Astronomical Expedition to the Southern Hemisphere during the years 1849 to 1852. Gilliss.
Useful Information for Engineers. Fairbairn, 1866,
Van Nostrand's Engineering Magazine. 25 vols.
Ventilation and Warming of Buildings. Ruttan, 1862.
Villas and Cottages. Downing, 1857.
Vosburg Tunnel. 1887.
Wear of Rails as Related to their Section. Dudley, 1890.
What Shall We Do With Our Walls? Cook, 1881.
Wonderful Inventions. Timbes
Workshop. 1868 to 1870 3 vols.
Fourteen Photographs of Conemaugh Dam and Vicinity.
Framed photograph of the Manhattan Life Insurance Building. New York.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

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CONTENTS:

THE LAKE FRONT IMPROVEMENTS OF THE ILLINOIS CENTRAL RAILROAD IN CHICAGO.

By JOHN FINDLEY WALLACE, M. Am. Soc. C. E.

TO BE PRESENTED SEPTEMBER 1ST, 1897.

History.—The original Illinois Central Railroad was chartered in 1850, to build a line from Cairo, at the junction of the Ohio and Mississippi Rivers, to Dubuque, Ia., with a branch line from the present city of Centralia, Ill., to Chicago. This line was constructed in 1852, entering Chicago along the shore of Lake Michigan and having its terminal station located between Randolph Street and the Chicago River. The southern limit of the city at that time was Twenty-second Street. The right of way of the railroad was purchased in fee simple

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

up to what is known as Park Row, near Twelfth Street, while from Park Row to Randolph Street a right of way 300 ft. wide was granted by the city under an ordinance dated June 14th, 1852, the railroad company agreeing to build a wall or breakwater along the outside edge of its right of way as far as the southern limits of the city, in order to protect the city shore line from the encroachments of Lake Michigan. But as the railroad's charter from the State of Illinois specifically determined that its right of way should be 200 ft. in width, the railroad company was restricted to that width, and it therefore constructed the breakwater on the outside edge of the 200-ft. right of way in accordance with the provisions of the ordinance.

A considerable portion of what is now solid ground east of Michigan Avenue, from Park Row to Randolph Street, a distance of 5 995 ft., was at that time Canal Lands, and Michigan Avenue was platted on the city maps without any eastern boundary; the west line of Michigan Avenue, however, was definitely fixed and the property west of that thoroughfare was laid out in lots, streets and alleys. But on the east side, the width of Michigan Avenue was supposed to extend to the shore of the lake, as there was at that time no appreciable amount of land east of the roadway.

The Illinois Central Railroad was originally constructed as a single-track line on a trestle, and the western boundary of its right of way was 400 ft. east of the west line of Michigan Avenue, the waters of Lake Michigan occupying the intermediate space between the railroad track and the avenue.

After the fire of 1871, this space was filled with débris from the ruins, as well as a large part of the Illinois Central right of way; and the ground between Michigan Avenue and the west line of the railroad right of way became known as the Lake Front Park.

In 1869 the Legislature of the State of Illinois by an act granted to the Illinois Central Railroad Company the right to all submerged land east of its right of way for a distance of 1 mile into the lake and between the Chicago River and its round-house south of Fourteenth Street, a distance of 1.85 miles, the fee to the submerged land constituting the bed of Lake Michigan being vested in the State. This grant was, of course, subject to the establishment of a shore and dock line either by the State or United States officials. In 1873 this act was repealed.

The matter was finally taken into the United States Court, the Illinois Central Railroad Company claiming that the State had no constitutional power to pass the repealing act, which amounted to the annulment of the contract. The City of Chicago interfered in the case, claiming that the fee to all the submerged land previously granted to the railroad company belonged to it (the city), taking the ground that the city owned the riparian rights along the lake front for the reason that the east line of Michigan Avenue was not defined by metes and bounds but was bounded on the east by the lake, and that therefore the city owned the riparian rights through its ownership of Michigan Avenue as a street. Other questions of interest were also involved, which brought into dispute the rights of the Illinois Central Railroad to not only the submerged land between Randolph Street and Park Row, but also to the piers which it had already constructed and the ground it had reclaimed from the lake between the Chicago River on the north and Sixteenth Street on the south, as well as to the occupancy of the lands, docks and wharves which it had previously acquired. Pending the trial of this case the railroad company was enjoined from extending its docks or properties into the waters of the lake.

The decision in the United States Court confirmed to the railroad company the right to all the ground and property it had acquired and was in possession of at the time of the commencement of the litigation, but was unfavorable to the railroad company in other particulars. The case was finally carried to the Supreme Court and decision rendered in 1892, which in substance confirmed to the Illinois Central Company its title to all the submerged land, docks and wharves it had acquired by filling in the lake, but confirmed to the city its rights as riparian owner of the land filled in adjoining Michigan Avenue on the east. The decision further confirmed to the Illinois Central Railroad Company its perpetual and exclusive right for railroad purposes to the right of way occupied by it between Park Row and Randolph Street. Many minor points in the decision, however, settled principles of vast importance to both public and private corporations, in reference to the use, occupancy and ownership of water fronts.

The long-continued litigation between the city and the railroad company resulted in much public irritation, and the tenor of public opinion was adverse to the interests of the railroad company. Imme-

diately after the decision of the Supreme Court had been rendered, certain private citizens, in connection with the city government and the press, commenced an agitation which resulted in considerable friction between the railroad company and the public, the object being to force the company to depress its tracks along the lake front. Threats were made to open up various public streets intersecting Michigan Avenue across the tracks of the railroad company at grade, and objections were made to the railroad company fencing in its right of way in order to prevent accidents. The seriousness of these demands and the injury they would work to the public as well as the railroad company can be more easily understood when it is stated that at this time the Illinois Central right of way, 200 ft. in width, and extending from Park Row to Randolph Street, was occupied by twelve or thirteen tracks, over which there were more than 1 000 engine movements in every twenty-four hours, in addition to the partial or switching movements made at the north end of the passenger yards near Park Row and over the switching leads in and out of the Randolph Street yard extending southward.

Prior to 1892 thousands of people were continually crossing the tracks at grade, in order to obtain access to the lake for boating, fishing or other pleasure purposes. The difficulty was partially remedied during the World's Columbian Exposition of 1893 by the construction of a viaduct across these tracks at Van Buren Street and the building of a fence along the west line of the right of way between Randolph Street and Park Row.

In 1894 the city authorities insisted on the removal of the viaduct, the taking down of the fence and the throwing open to the public of the entire right of way between these points, in spite of the known fact that accidents endangering life and limb would be of daily occurrence. This demand was undoubtedly intended to force the railroad company to some permanent settlement of the difficulty.

The situation became extremely critical. After the railroad company had offered to construct foot viaducts over its tracks at such points as the city might designate, and had been refused permission to do so, the officials of the railroad company, in conference with the city officials, finally agreed on a compromise of the entire matter. This resulted in the passage of an ordinance dated October 21, 1895, by Chicago City Council, and the subsequent execution of a con-

tract in accordance therewith between the city and the railroad company.

This contract provided that the Illinois Central Railroad should do the following work:

1. Depress its tracks on the Lake Front between Park Row and Randolph Street to a depth of approximately 4 ft., according to certain grades specified in the agreement.

2. Construct a sea wall along what is known as the dock line, approximately 1 200 ft. east of the Illinois Central right of way, from Randolph Street to the vicinity of Park Row extended, with a return

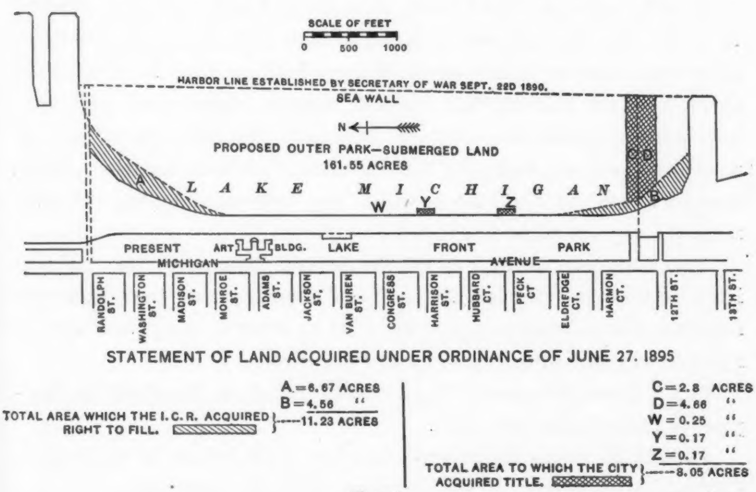


FIG. 1.

wall to the shore; also to construct certain piers in order to form a yacht harbor at 12th Street.

3. Build retaining walls on each side of its right of way, as described in said agreement.

4. Deliver 200 000 cu. yds. of filling in the Lake Front Park between the Illinois Central right of way and Michigan Avenue.

5. Construct four viaducts for carriages at such streets as should be selected by the city authorities, and one viaduct for pedestrians at the foot of each of the other streets intersecting Michigan Avenue, which, if projected, would cross the Illinois Central right of way between the two points named.

6. Extend and rebuild as much of the Randolph Street viaduct as might be necessary to obtain access to the new park which it is the intention of the city to construct between the east line of the Illinois Central right of way and the sea wall before mentioned.

7. Construct a new suburban station at Van Buren Street, 300 ft. long and 50 ft. wide.

8. Cede to the city certain riparian rights to 7.46 acres of land, and further cede to the city 0.59 acre of ground which it (the railroad company) had previously filled in and utilized; making a total of 8.05 acres.

In return for this the Illinois Central Railroad Company received from the city the right to fill in and occupy 6.67 acres of land between Adams and Randolph Streets; 1.26 acres between Park Row and Peck Court to which the city had claimed riparian rights; and 3.30 acres between the south line of Park Row and the 13th Street pier, to which the railroad company had heretofore claimed riparian rights; making a total of 11.23 acres which the railroad company obtained from the city the right to fill and occupy.

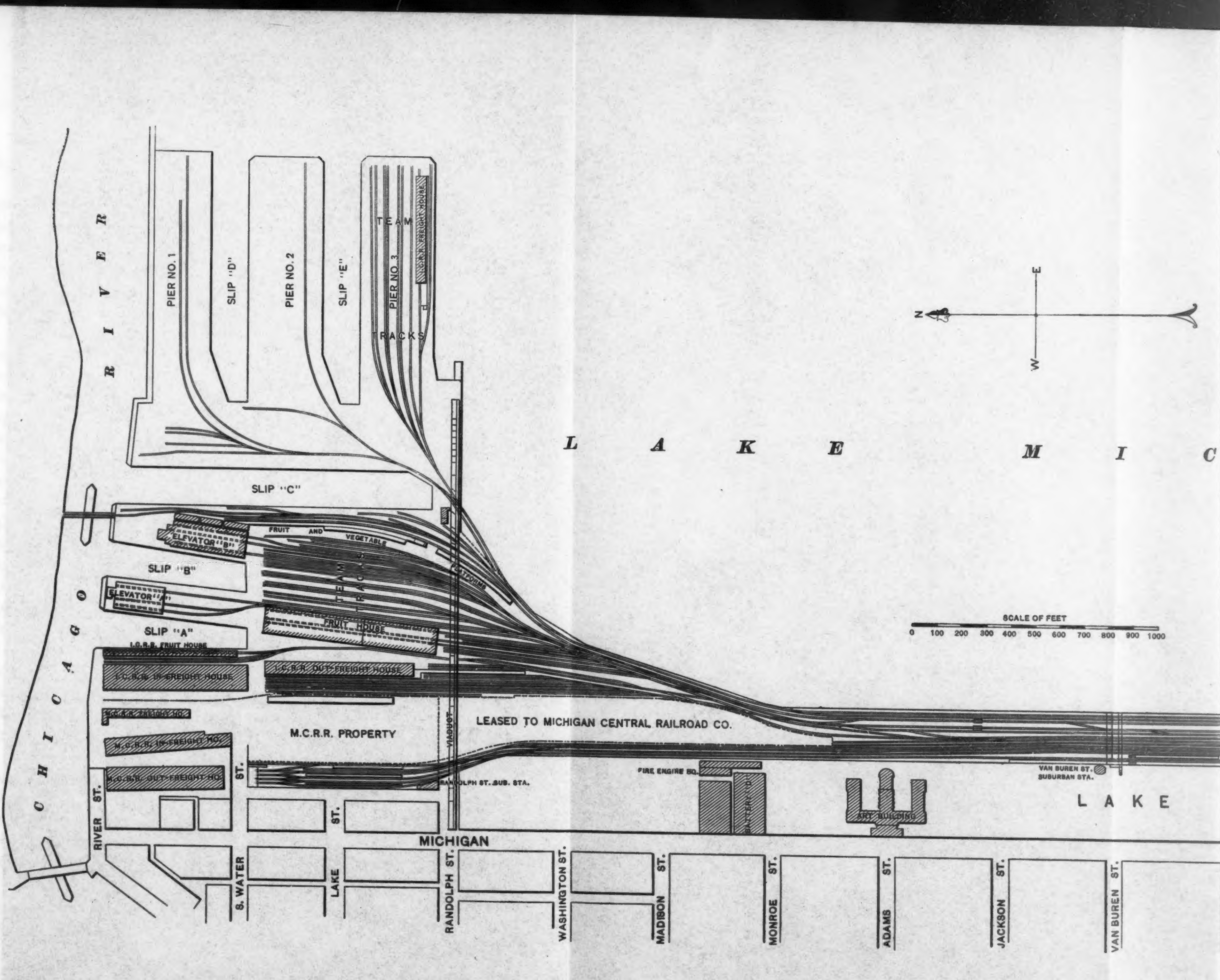
This agreement forever ended the general differences that had existed between the city and the railroad company for years, and confirmed to the railroad company its right to forever enjoy and use its right of way and property north of Park Row.

Fig. 1 shows the areas of land transferred from the railroad company to the city and *vice versa.*

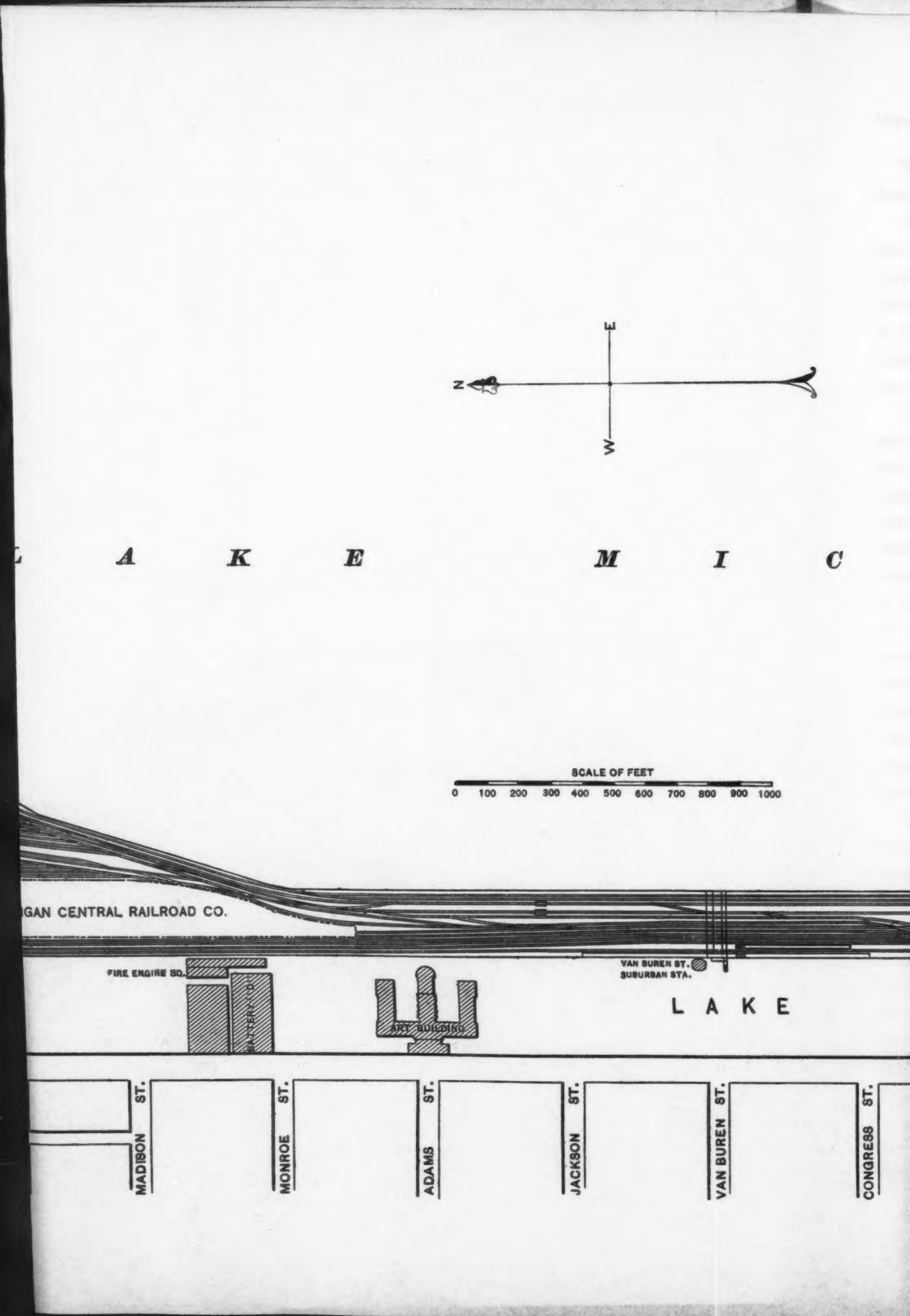
Plate XIII shows the original location of the tracks of the Illinois Central Railroad prior to the carrying out of this agreement.

Plate XIV shows the completed plan of the tracks which the acquisition of the additional land enabled the railroad company to construct.

The work of carrying out the provisions of this ordinance was commenced almost immediately after its passage and the acceptance of the contract, and up to the time of writing of this paper the following portions have been completed: Depression and rearrangement of tracks; west retaining wall; sea wall; Van Buren Street station; viaducts at Harrison Street, Peck Court and Van Buren Street; filling of the triangular pieces of submerged land acquired from the city; filling of Lake Front Park, between Michigan Avenue and railroad right of way.

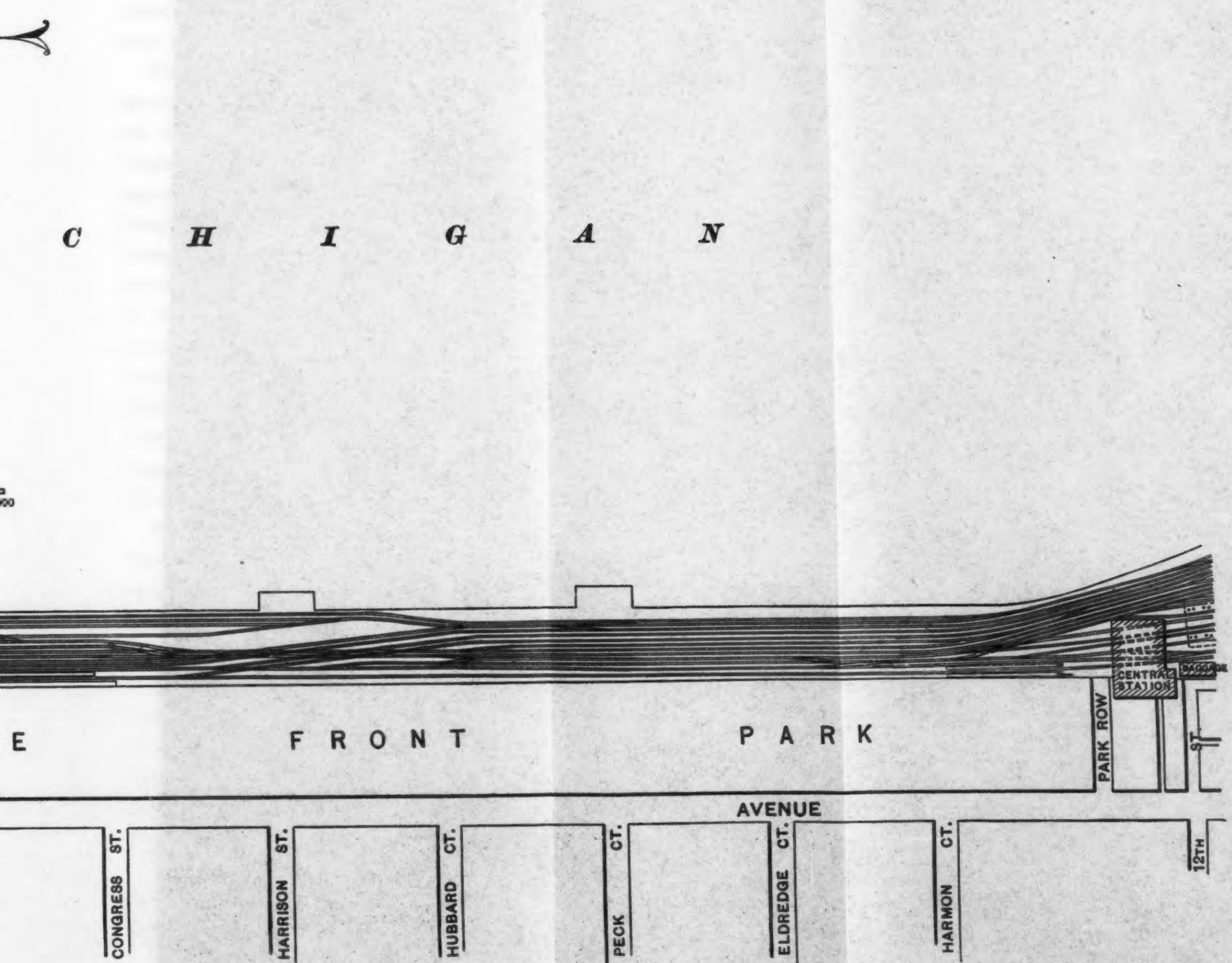


CHICAGO RIVER
PIER NO. 1
SLIP "D"
PIER NO. 2
SLIP "E"
PIER NO. 3
TEAM TRACKS
SLIP "C"
FRUIT AND VEGETABLE
ELEVATOR "B"
SLIP "B"
ELEVATOR "A"
TEAM TRACKS
FRUIT HOUSE
SLIP "A"
I.C.R.R. FRUIT HOUSE
I.C.R.R. IN-FREIGHT HOUSE
I.C.R.R. OUT-FREIGHT HOUSE
M.C.R.R. FREIGHT HO.
M.C.R.R. IN-FREIGHT HO.
M.C.R.R. OUT-FREIGHT HO.
M.C.R.R. PROPERTY
LEASED TO MICHIGAN CENTRAL RAILROAD CO.
VIADUCT
RANDOLPH ST. SUB. STA.
FIRE ENGINE HO.
ART BUILDING
VAN BUREN ST. SUBURBAN STA.
LAKE MIC
LAKE
N
E
W
SCALE OF FEET
0 100 200 300 400 500 600 700 800 900 1000
MICHIGAN
RIVER ST.
S. WATER ST.
LAKE ST.
RANDOLPH ST.
WASHINGTON ST.
MADISON ST.
MONROE ST.
ADAMS ST.
JACKSON ST.
VAN BUREN ST.



L A K E M I C
SCALE OF FEET
0 100 200 300 400 500 600 700 800 900 1000
GAN CENTRAL RAILROAD CO.
FIRE ENGINE HO.
BATTERY "D"
ART BUILDING
VAN BUREN ST. SUBURBAN STA.
L A K E
MADISON ST.
MONROE ST.
ADAMS ST.
JACKSON ST.
VAN BUREN ST.
CONGRESS ST.

PLATE XIII.
PAPERS AM. SOC. C. E.
AUGUST, 1897.
WALLACE ON LAKE FRONT IMPROVEMENTS.



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These Lake Front improvements were estimated to cost, when finally completed, $1 200 000.

Depression and Rearrangement of Tracks.—The general level of Michigan Avenue is 12 to 15 ft. above the Chicago city datum, datum being based upon the low water in Lake Michigan. The recorded fluctuation of water in the lake has varied from about 1 ft. below to 4 ft. above low water (city datum), making a total variation of approximately 5 ft. The general elevation of the Illinois Central tracks varied from 9 ft. above at Randolph Street to 11 ft. above at Park Row.

The city authorities desired the tracks depressed to the maximum amount in order that bridges might be built over them at points opposite the extensions of certain streets to connect with the proposed larger park east of the Illinois Central right of way, with moderate approaching grades from Michigan Avenue to the western end of these bridges. At one time the city contemplated the depression of the tracks below the level of Lake Michigan and roofing them over except at suitable intervals for ventilation, in order to hide entirely the sight of cars and trains from the adjoining city parks. This was quite impracticable, not only on account of the enormous expense it would have entailed, but also by reason of the difficulty in the way of obtaining suitable drainage, as well as on account of the location of the Central Station south of Park Row and the local freight houses and freight terminal tracks north of Randolph Street, the switching leads for which extended as far south as Van Buren Street.

The railroad company contended that it should not be required to lower its tracks to any greater depth than would be necessary to enable proper viaducts to be constructed with suitable approaches thereto, and that would allow drainage to be secured into Lake Michigan by gravity.

The final result was an agreement that the railroad company should depress its tracks to a grade of 6 ft. above city datum at each edge of the 200-ft. right of way, with a crowning transverse grade to 7 ft. in the center; the object being to deflect the drainage to either side of the right of way and then take care of it by a system of sewerage affording subdrainage.

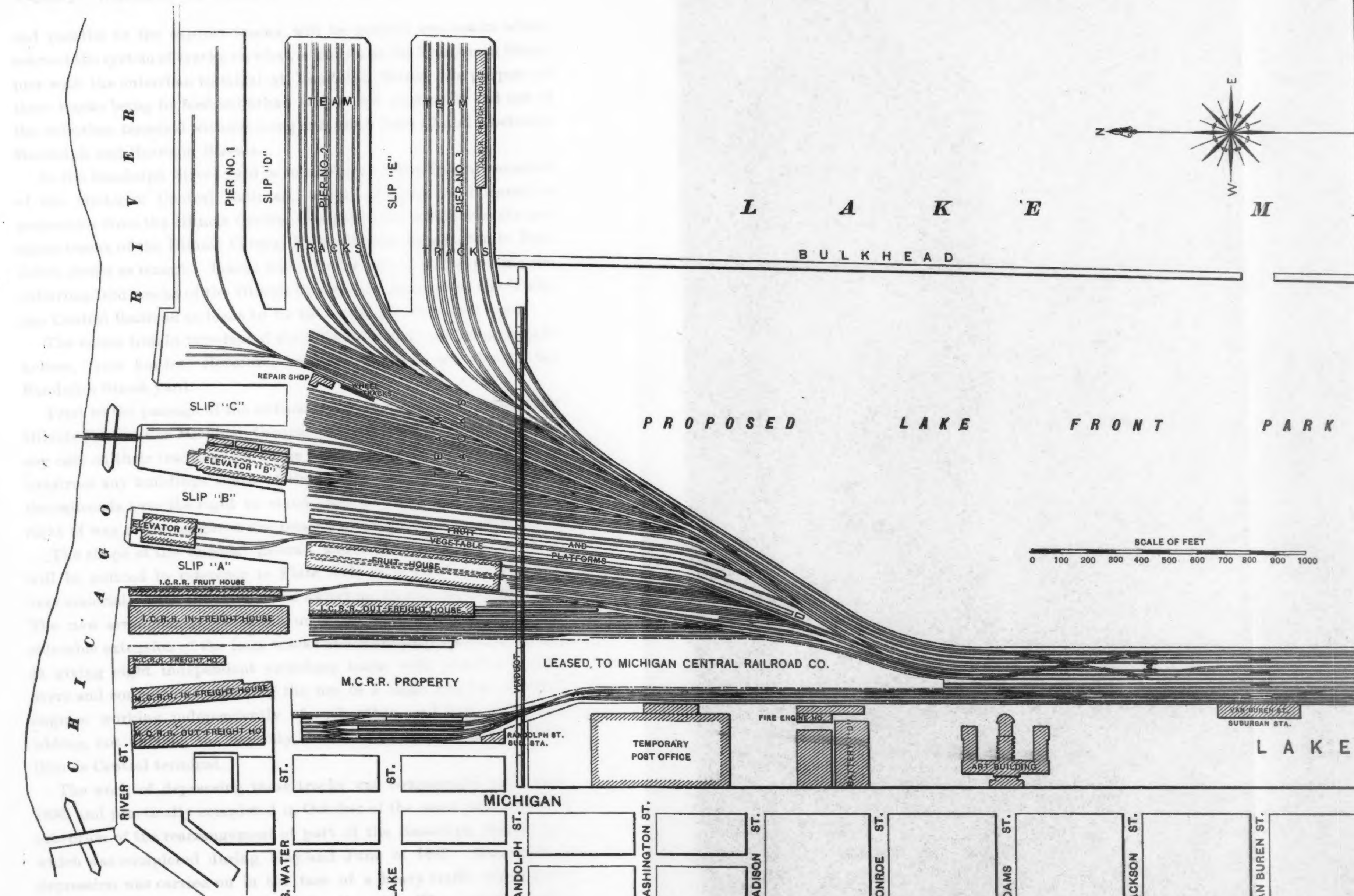
Owing to the requirements of the city preventing the use of deep girders or long pin-connected spans for the various viaducts, it was necessary to construct these viaducts of comparatively short spans with

intermediate supports, which in turn necessitated an entire rearrangement of the tracks. The track problem, therefore, not only consisted of the depression of the tracks under traffic, but their entire rearrangement as well.

A careful examination of the track plans, showing the lay-out of tracks before and after this work was done, will show that each track was designed to perform a certain function. A brief description of the business done over these tracks is necessary to an intelligent understanding of the plan.

The business of the Illinois Central Railroad on the Lake Front north of Park Row is varied and complex in character. The tracks north of Randolph Street, next to Central Avenue, are the suburban terminal tracks, Randolph Street being the terminal for all suburban trains. What is known as the local suburban service occupies tracks 1 and 2 on the west edge of the right of way, the trains in this service making stops at all stations and running southward as far as Sixty-third Street. What is known as the express suburban service makes use of the same terminal station at Randolph Street, and follows the same tracks 1 and 2 as far as Van Buren Street, where it uses the same station also, south of that point diverging and running entirely around the Central Station at Twelfth Street, these express tracks being so located as to be interfered with and cut into by frogs and switches as little as possible. After leaving the junction with tracks 1 and 2 south of Van Buren Street and passing over the crossing at Harrison Street, these tracks are cut by only two sets of cross-overs, at Twenty-seventh and Forty-third Streets, in the entire distance of 9 miles between Randolph and Seventieth Streets, the latter point, however, that is, Forty-third Street, being protected and controlled by an interlocking plant. There are no street crossings at grade north of Seventieth Street. The crossing at Harrison Street was selected as the neutral point, north of which all the switching in and out of the Randolph Street yard is done, while all switching in and out of the passenger yards at Twelfth Street is performed south of this point, confining the movements crossing the express suburban tracks at Harrison Street entirely to through movements by trains and transfers in and out of the Randolph Street yard to other points on the Illinois Central system and connecting lines.

Parallel to tracks 1 and 2, leading out of Randolph Street station,


CHICAGO RIVER
PIER NO. 1
SLIP "D"
TEAM
PIER NO. 2
SLIP "E"
TEAM
PIER NO. 3
TRACKS
TRACKS
BULKHEAD
L A K E M
N
E
W
REPAIR SHOP
SLIP "C"
ELEVATOR "B"
SLIP "B"
ELEVATOR
SLIP "A"
TEAM TRACKS
FRUIT VEGETABLE AND PLATFORMS
FRUIT HOUSE
I.C.R.R. FRUIT HOUSE
I.C.R.R. IN-FREIGHT HOUSE
I.C.R.R. OUT-FREIGHT HOUSE
M.C.R.R. FREIGHT HO.
M.C.R.R. IN-FREIGHT HOUSE
M.C.R.R. OUT-FREIGHT HO.
M.C.R.R. PROPERTY
VIADUCT
RANDOLPH ST. SUB. STA.
PROPOSED LAKE FRONT PARK
SCALE OF FEET
0 100 200 300 400 500 600 700 800 900 1000
LEASED TO MICHIGAN CENTRAL RAILROAD CO.
TEMPORARY POST OFFICE
FIRE ENGINE HO.
BATTERY
ART BUILDING
VAN BUREN ST. SUBURBAN STA.
LAKE
MICHIGAN
RIVER ST.
S. WATER ST.
LAKE ST.
RANDOLPH ST.
WASHINGTON ST.
MADISON ST.
MONROE ST.
ADAMS ST.
JACKSON ST.
VAN BUREN ST.

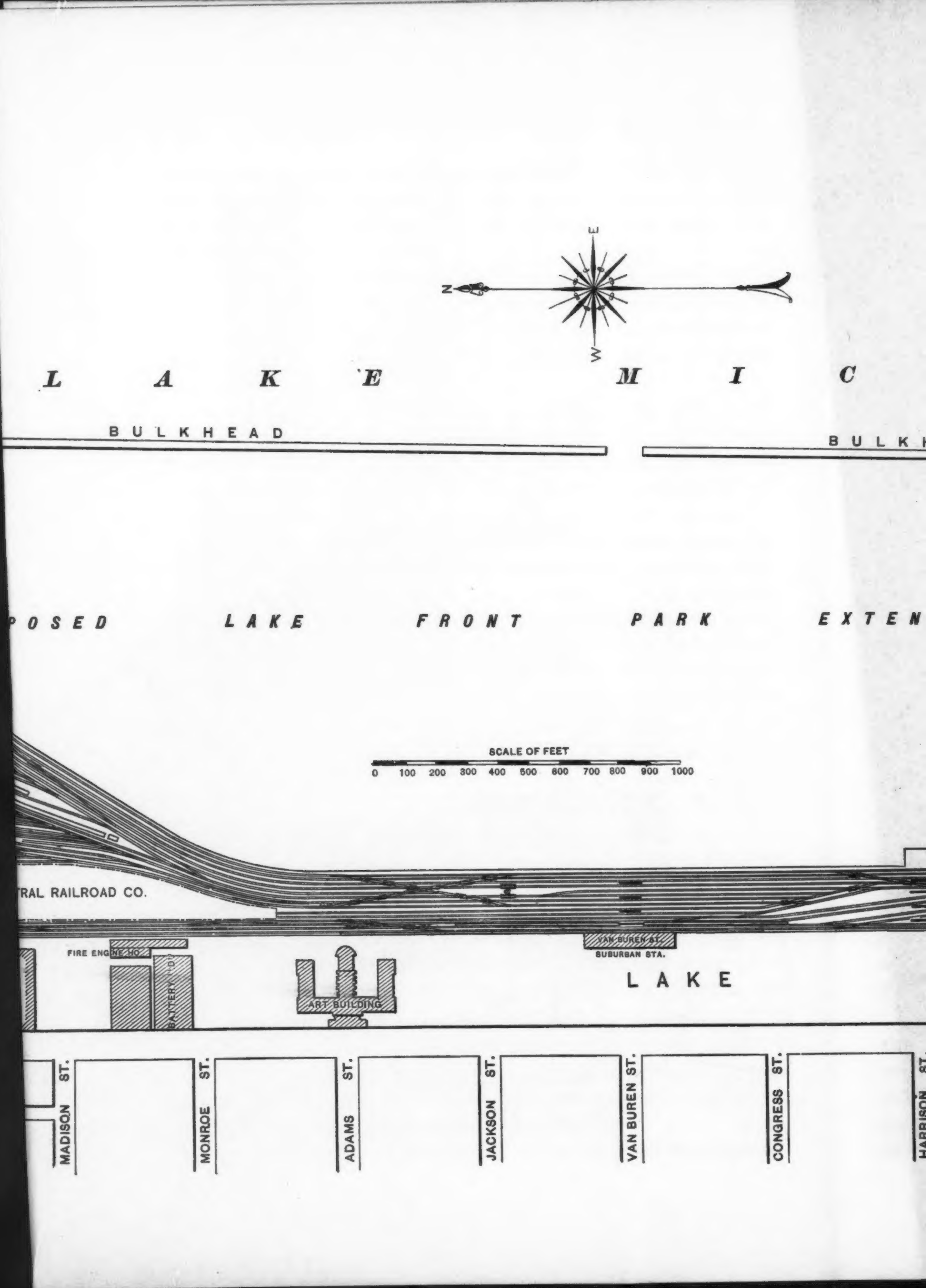
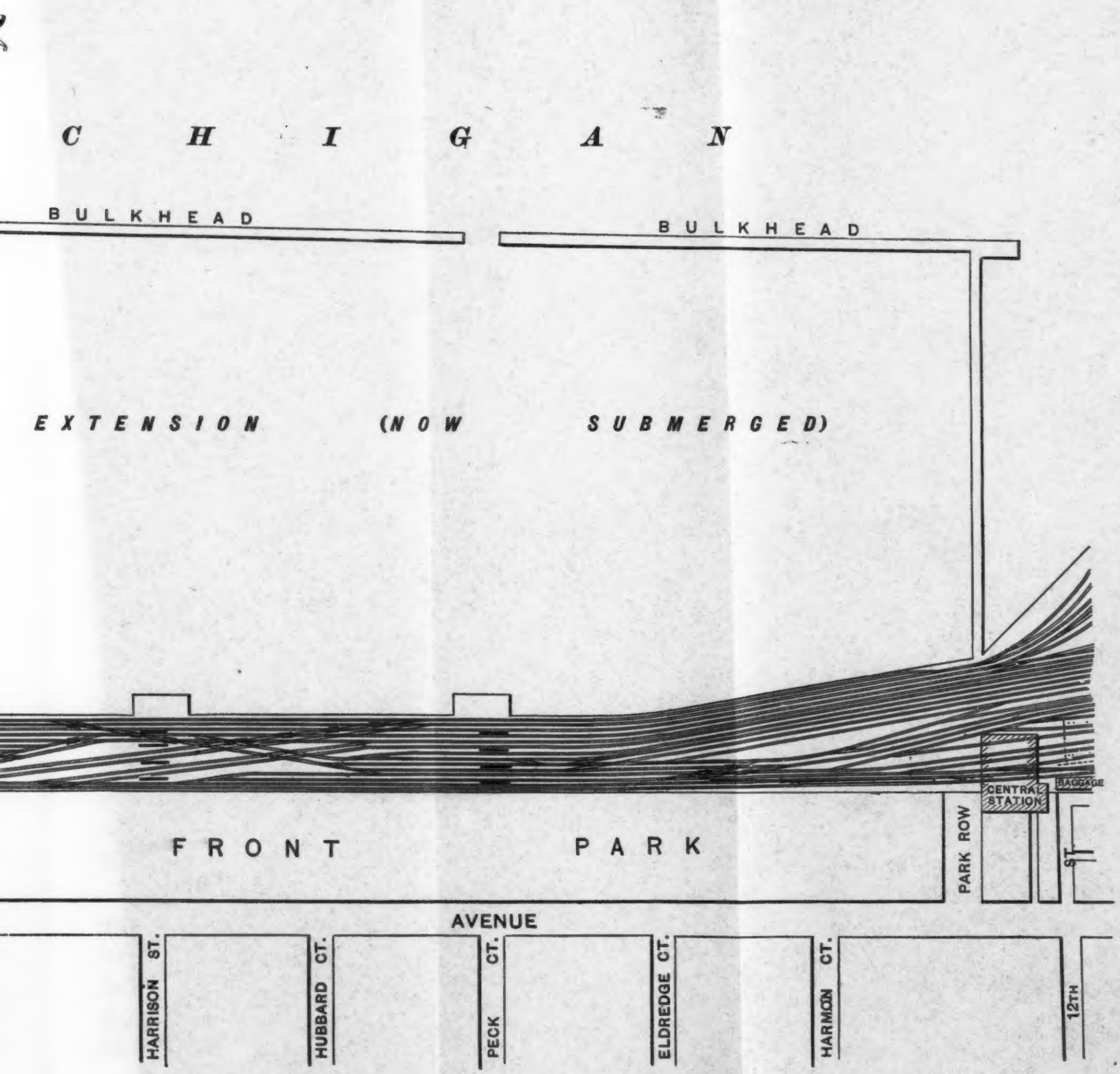

N
E
W
L A K E M I C
BULKHEAD
BULKH
POSED LAKE FRONT PARK EXTEN
SCALE OF FEET
0 100 200 300 400 500 600 700 800 900 1000
TRAL RAILROAD CO.
FIRE ENGINE HO.
BATTERY "D"
ART BUILDING
VAN BUREN ST. SUBURBAN STA.
LAKE
MADISON ST.
MONROE ST.
ADAMS ST.
JACKSON ST.
VAN BUREN ST.
CONGRESS ST.
HARRISON ST.

PLATE XIV.
PAPERS AM. SOC. C. E.
AUGUST, 1897.
WALLACE ON LAKE FRONT IMPROVEMENTS.



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and parallel to the express tracks, will be noticed two tracks which connect the system of tracks on what is known as the Thirteenth Street pier with the suburban terminal at Randolph Street, the purpose of these tracks being to feed suburban trains and engines in and out of the suburban terminal without using or fouling tracks 1 and 2 between Randolph and Harrison Streets.

In the Randolph Street yard is located the entire freight terminal of the Michigan Central Railroad, which occupies land leased in perpetuity from the Illinois Central Company, and which uses the terminal tracks of the Illinois Central Railroad from Kensington to Randolph Street as tenant. Tracks 4 and 5 next east of and adjoining the suburban feed tracks of the Illinois Central are assigned to the Michigan Central Railroad as leads to its Randolph Street freight yard.

The entire freight terminal of the Illinois Central, including freight houses, fruit houses, elevators, team yards, etc., are also in the Randolph Street yard.

Prior to the passage of the ordinance above mentioned, neither the Illinois Central nor Michigan Central railroads had the right to stand any cars on their tracks south of the north line of Randolph Street, or construct any buildings south of that point. By the new agreement the railroads have the right to stand cars or erect structures on the right of way to the height of the retaining wall or the parapet thereon.

The shape of the railroad ground under the old arrangement, as will be noticed by reference to Plate XIII, was such as to interfere very materially with the economical switching in and out of this yard. The new arrangement, as shown on Plate XIV, provides for a considerable extension of the team tracks and other yard facilities, as well as giving eight independent switching leads, with necessary cross-overs and connections, allowing the use of a large number of switch engines working independently of each other, and thus materially adding, not only to the capacity, but also to the efficiency, of the Illinois Central terminal.

The work of depressing these tracks was commenced April 15th, 1896, and practically completed in October of the same year, with the exception of the rearrangement of part of the Randolph Street yard, which was completed during May and June of 1897. This work of depression was carried on in the face of a heavy traffic without any delay to trains and without any derailments. The material taken

from under the tracks was used to assist in filling the triangular pieces of land acquired by the company under the agreement with the city.

One of the main difficulties in handling this work was the fact that several of the middle tracks were originally built on trestle piling, and during the depression it was necessary to excavate around the piling and frequently to remove each separate pile, piece by piece, the greater part of the piling being well preserved. The piles were pulled up by switch engines.

It was, of course, necessary to excavate material approximately 1 ft. below sub-grade, this space being refilled with slag, which was used for ballasting all the tracks except the express suburban, these being ballasted with crushed rock. The volume of earth in this excavation was 110 000 cu. yds. Fourteen miles of track were depressed; and 10 crossings, 34 double-slip switches and 102 single-slip switches were depressed or laid on the new plan. The cost of the depression was $57 000, averaging a cost of 78 cents per foot, including rearrangement of tracks, ballasting and surfacing on the various temporary locations which they occupied during the progress of the work. Fig. 2 shows cross-sections of the old and new track plans at points where the greatest depression was made.

The Sea Wall.—The object of the sea wall was to form an outer boundary of the new park which the city was endeavoring to provide for by this agreement with the railroad company, containing practically 165 acres in all, being 5 900 ft. in length, by an average of 1 350 ft. in width. This sea wall was constructed on a harbor line which had been previously established by the United States engineers.

The plans and specifications for the sea wall were furnished by Major W. L. Marshall, M. Am. Soc. C. E., of the Corps of Engineers of the United States Army, and the permit for its construction required a strict conformity to the plans and specifications furnished by him. As the City of Chicago expected to do a large amount of filling in the new outer Lake Front Park from the material dredged from the Chicago River and the Drainage Canal, the United States Government required that the sea wall be constructed before it would permit the dumping of any of this material in the area to be filled, in order that the filling might be effectually confined and prevent the shoaling up of the outer harbor. Sketches showing the manner of construction of the sea wall are given in Fig. 3.

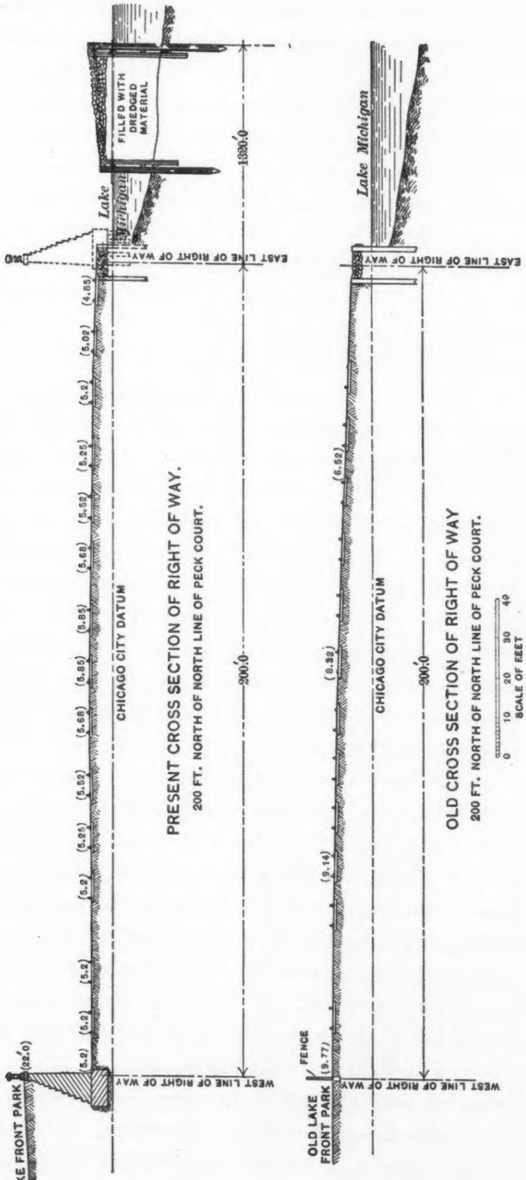

PRESENT CROSS SECTION OF RIGHT OF WAY.
200 FT. NORTH OF NORTH LINE OF PECK COURT.
OLD CROSS SECTION OF RIGHT OF WAY
200 FT. NORTH OF NORTH LINE OF PECK COURT.
CHICAGO CITY DATUM
EAST LINE OF RIGHT OF WAY
WEST LINE OF RIGHT OF WAY
LAKE FRONT PARK
OLD LAKE FRONT PARK
FENCE
Lake Michigan
FILLED WITH DREDGED MATERIAL
1320.0
200.0
SCALE OF FEET

FIG. 2.

Work on the sea wall was commenced in November, 1895, but operations were soon suspended on account of stormy weather and the approach of winter. Early in the spring of 1896 work was resumed, and the wall finally completed October 1st, 1896. The following quantities of material were contained therein: 105 000 lin. ft. of piling; 2 233 000 ft. B. M. pine sheeting; 659 000 ft. B. M. waling; 3 433 cords of stone. These figures are round numbers. The amount of earth filling cannot be given, as this material was dredged from the bed of the lake directly into the bulkhead and no record was kept of it. The entire work cost in round numbers $220 000. Altogether, 7 200 lin. ft. of sea wall were constructed.

Inner Lake Front Park.—What was formerly known as the Lake Front Park was the strip of land 310 ft. in width, between Michigan Avenue and the Illinois Central right of way, and, as already described, extending from Randolph Street to Park Row. As noted in the terms of the contract between the city and the railroad company, the latter was required to furnish 200 000 cu. yds. of filling, to be used in grading the inner park so that its surface would slope from Michigan Avenue upward to the top of the retaining wall along the west edge of the right of way, instead of sloping downward to the level of the tracks as formerly. This filling was supplied in a small measure from various excavations for building foundations in the city, but generally by train, the contractors doing this work having made arrangements with the contractors of the Drainage Canal southwest of Chicago for this material, which was loaded by steam shovel out of the cross-section of the canal directly on cars and transported by rail to the Lake Front Park, the haul being 8 miles. This work was completed in November, 1896, at a total cost of approximately $37 500.

The low price of this work was due mainly to the fact that the contractors excavating the Drainage Canal were required to get rid of the material at their own expense, and the contractor who filled the Park for the Illinois Central received pay from the Drainage Canal contractor for disposing of the material, which enabled him to do the work for the Illinois Central at a very low figure.

In the spring of 1897 the entire interest of the city in both the inner and outer Lake Front Park was transferred to the Board of South Park Commissioners, a special organization having control of the entire system of parks on the south side of the city. The

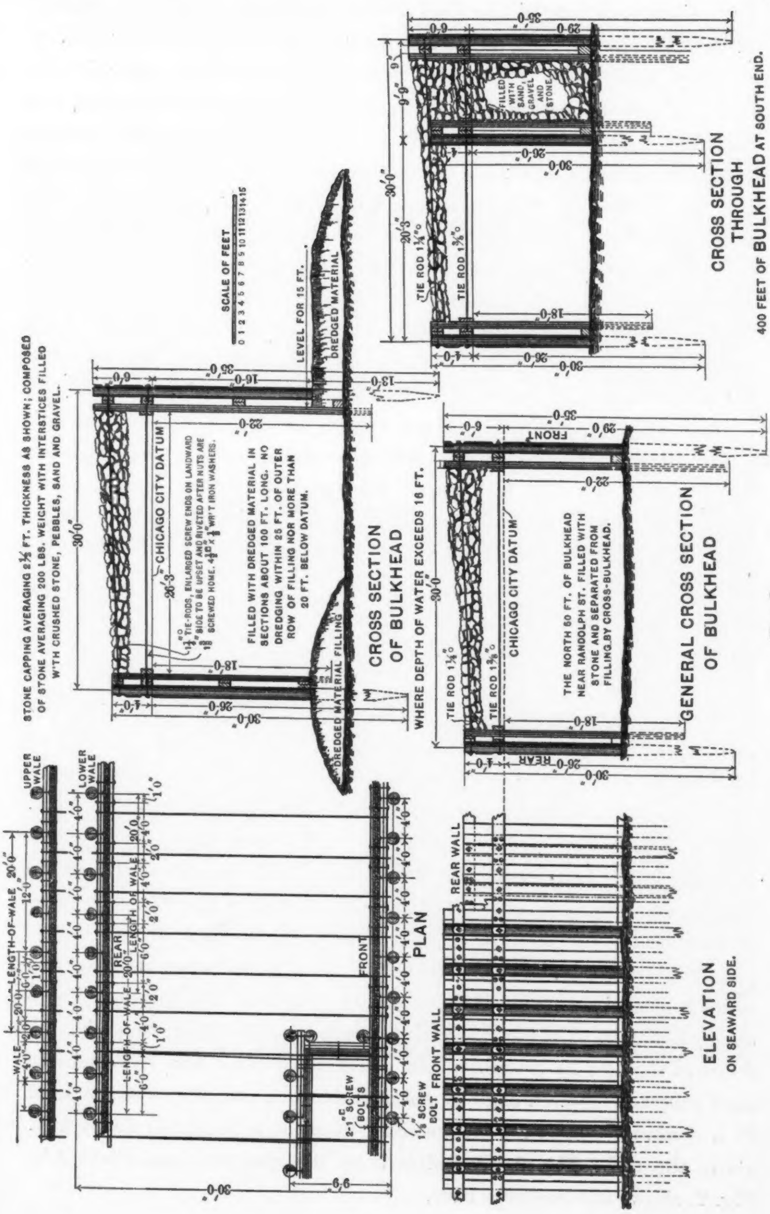

STONE CAPPING AVERAGING 2½ FT. THICKNESS AS SHOWN; COMPOSED OF STONE AVERAGING 200 LBS. WEIGHT WITH INTERSTICES FILLED WITH CRUSHED STONE, PEBBLES, SAND AND GRAVEL.
SCALE OF FEET
CHICAGO CITY DATUM
FILLED WITH DREDGED MATERIAL IN SECTIONS ABOUT 100 FT. LONG. NO DREDGING WITHIN 25 FT. OF OUTER ROW OF FILLING NOR MORE THAN 20 FT. BELOW DATUM.
LEVEL FOR 15 FT.
DREDGED MATERIAL
DREDGED MATERIAL FILLING
CROSS SECTION OF BULKHEAD
WHERE DEPTH OF WATER EXCEEDS 16 FT.
CROSS SECTION THROUGH
400 FEET OF BULKHEAD AT SOUTH END.
FILLED WITH SAND, GRAVEL AND STONE.
TIE ROD 1¼"○
TIE ROD 1⅜"○
THE NORTH 60 FT. OF BULKHEAD NEAR RANDOLPH ST. FILLED WITH STONE AND SEPARATED FROM FILLING BY CROSS-BULKHEAD.
GENERAL CROSS SECTION OF BULKHEAD
FRONT
REAR
UPPER WALE
LOWER WALE
LENGTH OF WALE
PLAN
ELEVATION
ON SEAWARD SIDE.
FRONT WALL
REAR WALL

FIG. 3.

Park Commissioners at the time of this writing have taken possession of the Lake Front Park and are now improving and beautifying it.

Outer Lake Front Park.—No provision has yet been made for the filling of the outer park. The area, as stated before, is 165 acres, and there is a depth of from 8 to 16 ft. of water in the basin, the average depth being about 12 ft. It is estimated that approximately 8 000 000 cu. yds. of material will be required to fill this area, according to the plans and grades that may be adopted. A recent act of the Legislature of the State of Illinois transferred to the South Park Commissioners whatever title the State might have had in the submerged land in question, and there were other provisions in the act which will eventually enable the Commissioners to complete the filling of the outer work.

Retaining Walls.—Among the works required to be done by the Illinois Central Railroad Company was the construction of two retaining walls, one on the west and one on the east side of the railroad right of way. The west wall has been constructed at a cost of $120 000 in round numbers, its length being about 6 000 ft. Sections of this wall are shown in Fig. 4.

The construction of the east wall is being deferred until the outer park will have been sufficiently filled to permit of safe and economical construction.

Viaducts.—At the time of writing this paper, viaducts have been erected at Peck Court and at Harrison and Van Buren Streets. These viaducts consist of five girder spans resting on two end abutments at each edge of the right of way, and four intermediate piers 40 ft. $3\frac{1}{2}$ ins. apart. These steel girders are of cantilever design, supported by steel columns imbedded in concrete foundations. This style of construction was necessary on account of the city authorities limiting the distance from the surface to the under side of the roadway of the viaduct (or, in other words, the thickness of the floors), it being necessary in order to comply with these requirements, and give the minimum necessary headway of $16\frac{1}{2}$ ft. for trains passing underneath, to make the floors as shallow as possible. In order to protect the intermediate steel columns from damage by possible derailments, they were encased in a concrete construction, forming piers at a height of about 4 ft. above the rail. Fig. 5 gives details of the viaducts, and Plate XV, Fig. 2, shows the concrete base.

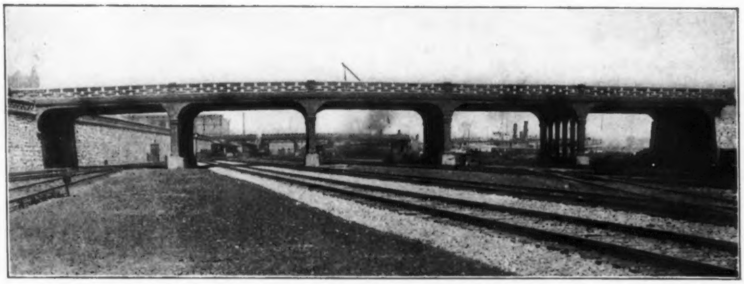


FIG. 1.

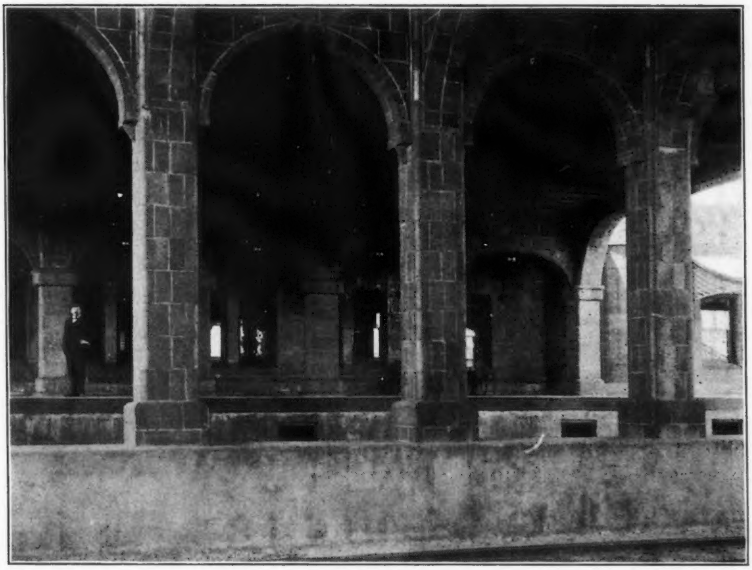


FIG. 2.

Owing to the large number of engine movements under these viaducts and the closeness of the under steel surfaces to the smokestacks of the engines, it was anticipated that unusually rapid deterioration of the steel work would occur from the action of the acids generated by the gases emanating from the engines. Experiments with various kinds of paint and thin coverings of steel work having heretofore proved ineffective, it was determined to treat this problem in a radical manner and protect the steel in these structures by surrounding it with an air-tight casing of terra cotta, sealing the joints with Portland

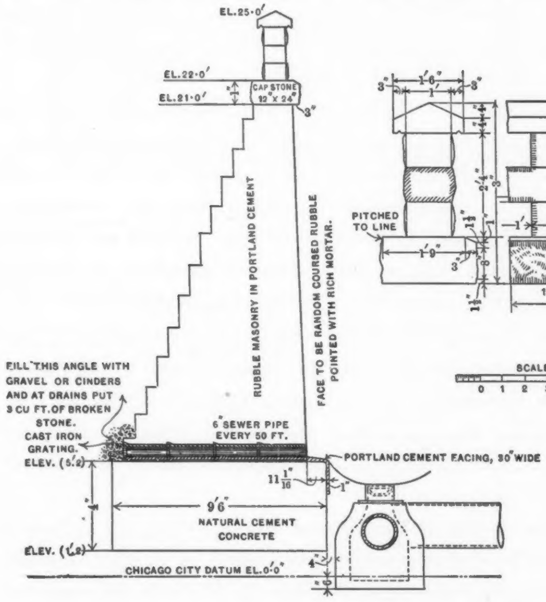


FIG. 4.

cement. The writer believes this form of treatment of bridges over railroad tracks to be original, and that it will prove a satisfactory solution of the problem. Plate XV, Fig. 1, shows the general appearance of one of these viaducts as completed. The Van Buren Street viaduct, which was slightly wider than the others, and more ornamental on account of its proximity to the station, cost $28 000.

Drainage.—Drainage for the depressed tracks has been provided by a complete system of sewers, shown in Fig. 6. The pipe used varied in size from 8-in. single to 24-in. double thickness, and has cost $9 000.

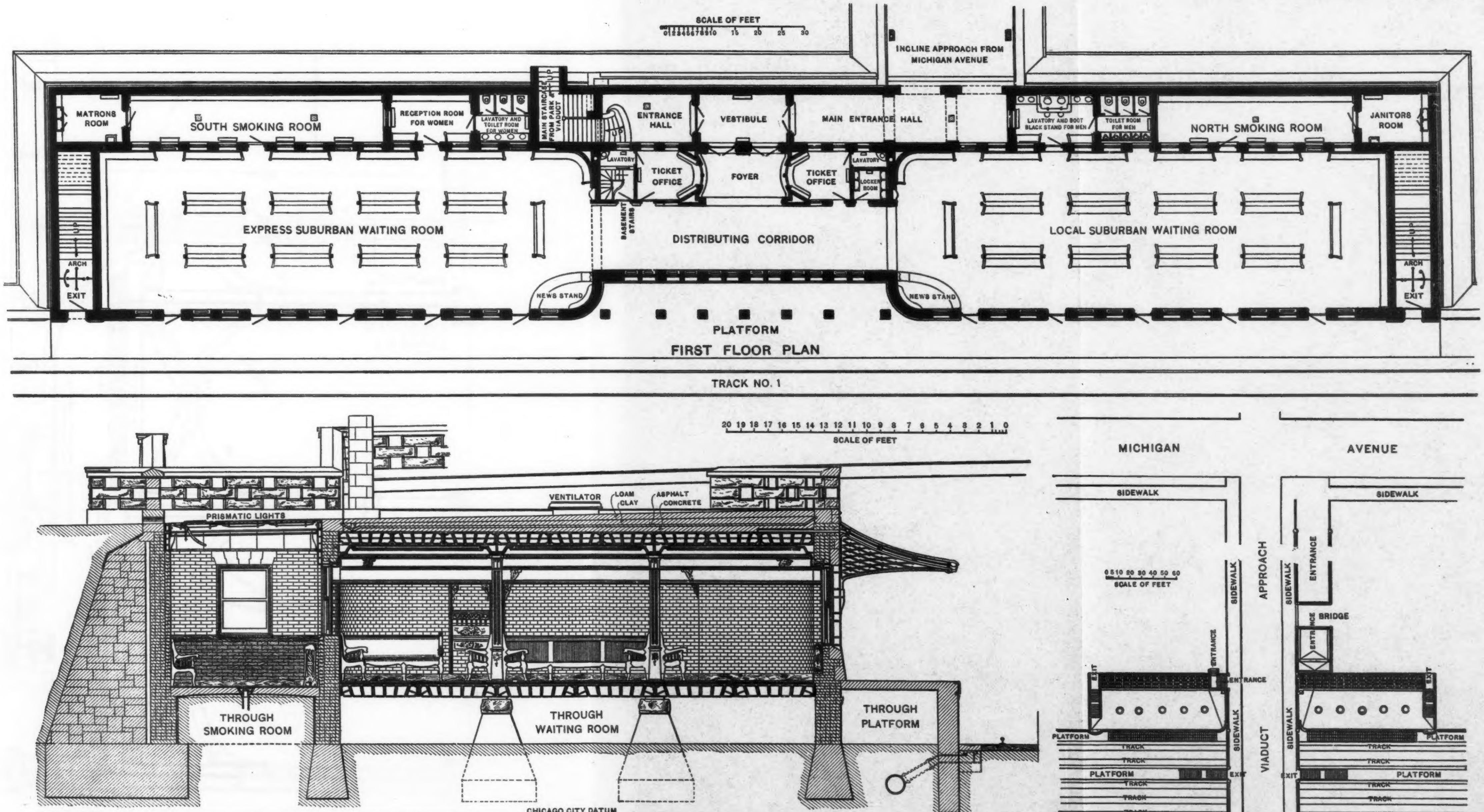
This sum, however, includes the cost of 230 ft. of 5-ft. pipe for the extension of the Twelfth Street sewer through the area filled in at that point.

Additional Filling.—The area acquired from the city in the vicinity of Randolph Street, 6.67 acres, required 127 500 yds. of material for filling, while the area filled at Park Row and vicinity required 129 000 yds. of material, a total of 256 500 yds. Part of this material was obtained by pumping in sand from the bed of the lake at a cost of 14 cents per cubic yard, the remainder of the filling being secured from the excavation for depressing the tracks, from slag hauled in by train, and in a small way from material dumped in by private parties. This work has been completed at a cost of $55 000.

Van Buren Street Station.—The contract with the city also provided for the construction by the Illinois Central Railroad Company of a suburban station at Van Buren Street. The ground assigned for this purpose was 300 ft. in length by 50 ft. in width, the city authorities requiring, however, that the roof of the building should not project above the general surface of the park or above the floor of the Van Buren Street viaduct, the center line of which passes directly over the station. It was further desired by the city authorities that this station should be so constructed as to permit of the growth of vegetation on its roof, so that, the station being underground, it would not take anything away from the surface area of the park. These limitations added materially to the difficulty of constructing a satisfactory station building.

The grade of the tracks at Van Buren Street being 5.2 ft. above Chicago datum, the floor of the station was made 9.75 ft. above datum, bringing it on a level with the outside platform of concrete construction which extended along the front of the station (with wooden extensions several hundred feet each way), and on a level with the platforms of the suburban coaches.

In order to give access to the station from Michigan Avenue without requiring the use of steps, a long incline approach was constructed, 27 ft. in width, having a concrete floor, with masonry retaining walls; starting from Michigan Avenue, immediately north of the approach to the Van Buren Street viaduct, and entering the station by two steps at the foot of the incline, this rise being necessary on account of drainage. Entrance is effected to the station by passing to the right under


SCALE OF FEET
INCLINE APPROACH FROM MICHIGAN AVENUE
MATRONS ROOM
SOUTH SMOKING ROOM
RECEPTION ROOM FOR WOMEN
LAVATORY AND TOILET ROOM FOR WOMEN
MAIN STAIRCASE FROM PARK VIADUCT
ENTRANCE HALL
VESTIBULE
MAIN ENTRANCE HALL
LAVATORY AND BOOT BLACK STAND FOR MEN
TOILET ROOM FOR MEN
NORTH SMOKING ROOM
JANITORS ROOM
LAVATORY
TICKET OFFICE
FOYER
TICKET OFFICE
LAVATORY
LOCKER ROOM
EXPRESS SUBURBAN WAITING ROOM
BASEMENT STAIRS
DISTRIBUTING CORRIDOR
LOCAL SUBURBAN WAITING ROOM
ARCH
EXIT
NEWS STAND
NEWS STAND
PLATFORM
FIRST FLOOR PLAN
TRACK NO. 1
SCALE OF FEET
PRISMATIC LIGHTS
VENTILATOR
LOAM
CLAY
ASPHALT
CONCRETE
THROUGH SMOKING ROOM
THROUGH WAITING ROOM
THROUGH PLATFORM
CHICAGO CITY DATUM
MICHIGAN
AVENUE
SIDEWALK
SIDEWALK
SCALE OF FEET
APPROACH
VIADUCT
ENTRANCE
BRIDGE
EXIT
PLATFORM
TRACK

Pa

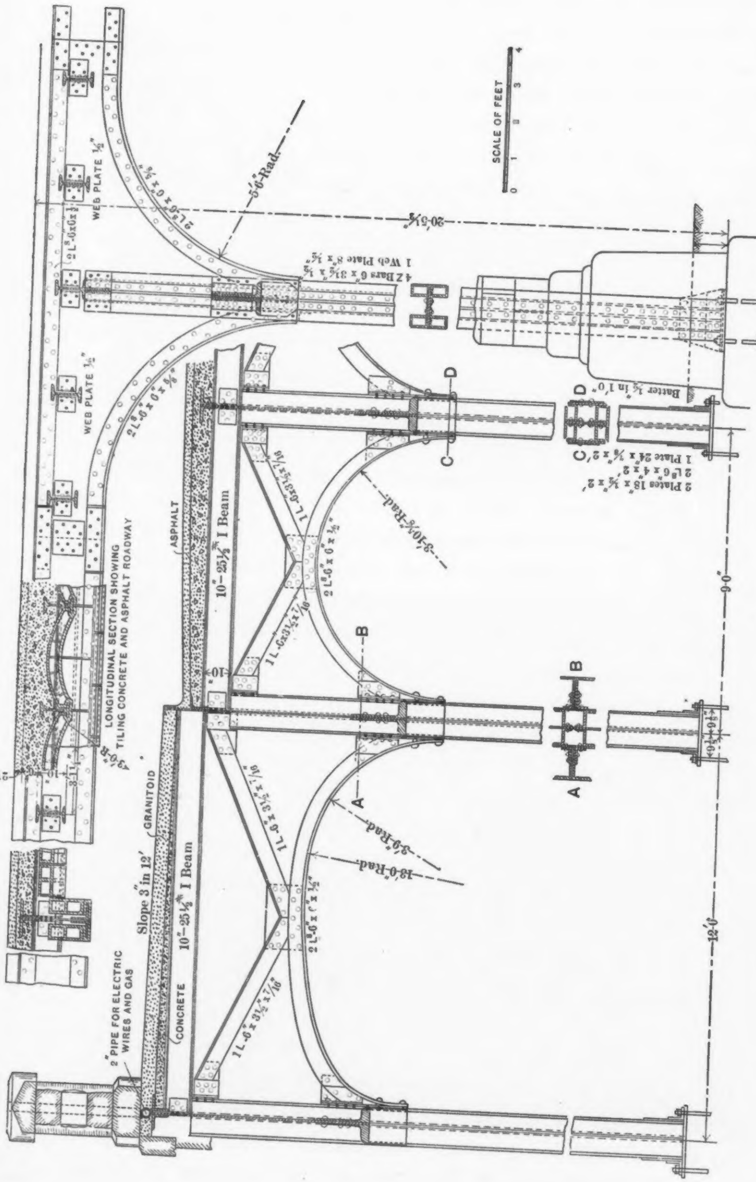

SCALE OF FEET
WEB PLATE ½"
5'0" Rad.
1 Web Plate 8" x ½"
4 Z Bars 6" x 3½" x ½"
Batter ½ in 1'0"
1 Plate 24 x ⅝" x 2'0"
2 Plates 18 x ½" x 2'
LONGITUDINAL SECTION SHOWING TILING CONCRETE AND ASPHALT ROADWAY
ASPHALT
GRANITOID
CONCRETE
10"–25½" I Beam
Slope 3" in 12'
2" PIPE FOR ELECTRIC WIRES AND GAS
3'10⅝" Rad.
5'9" Rad.
13'0" Rad.
A
B
C
D
9'0"
12'0"

FIG. 5.

the viaduct and into a loggia, which is flanked on either side by a ticket office; a connecting corridor from this, extending north and south into the main waiting rooms, each 106 x 34 ft., the north waiting-room being for passengers using the local suburban trains, and the south waiting-room for passengers using the express service. A space $10\frac{1}{2}$ ft. wide, extending the length of each waiting room, and in the rear, is set aside for toilet and smoking rooms and other conveniences. Over these is a prismatic roof, provided with suitably protected openings for ventilation, thus affording light and ventilation along the whole park side of the structure. On the track side of the station a continuous line of windows and doors gives light from that direction. In addition to this, a series of circular ventilators was placed in the middle of the roof over the main waiting rooms, at distances of about 19 ft. apart. This system of lighting and ventilation has proved satisfactory. Plate XVI shows the details of construction, and Plate XVII gives views of the exterior of the station and the main room.

A steam heating plant, in which natural gas is the generating power, is located in the basement, thus entirely avoiding any inconvenience and uncleanliness which would be caused by the use of coal for fuel. The station is lighted at night by electricity. The construction of the station is entirely and absolutely fireproof, the floors and roof being of girder construction, imbedded in terra cotta and concrete. The immediate covering of the floor is of vitrous tiling, while the side walls and intervening columns are covered with glazed tiling. No woodwork is used, except the doors and window casings and the seats, which are of cherry.

Work on this station was commenced on June 15th, 1896, and completed the last day of the same year, though a part of the building was put in service on December 14th. The entire cost was, in round numbers, $100 000.

The staff engaged in the design and execution of these Lake Front improvements, under the general direction of the author, was as follows:

David Sloan, M. Am. Soc. C. E., assistant chief engineer of the Illinois Central Railroad, had general charge of the depression and rearrangement of tracks, the filling of the park and the areas acquired by the railroad, and generally assisted the author.

H. W. Parkhurst, M. Am. Soc. C. E., engineer of bridges and

Fig. 1.

Fig. 2

P

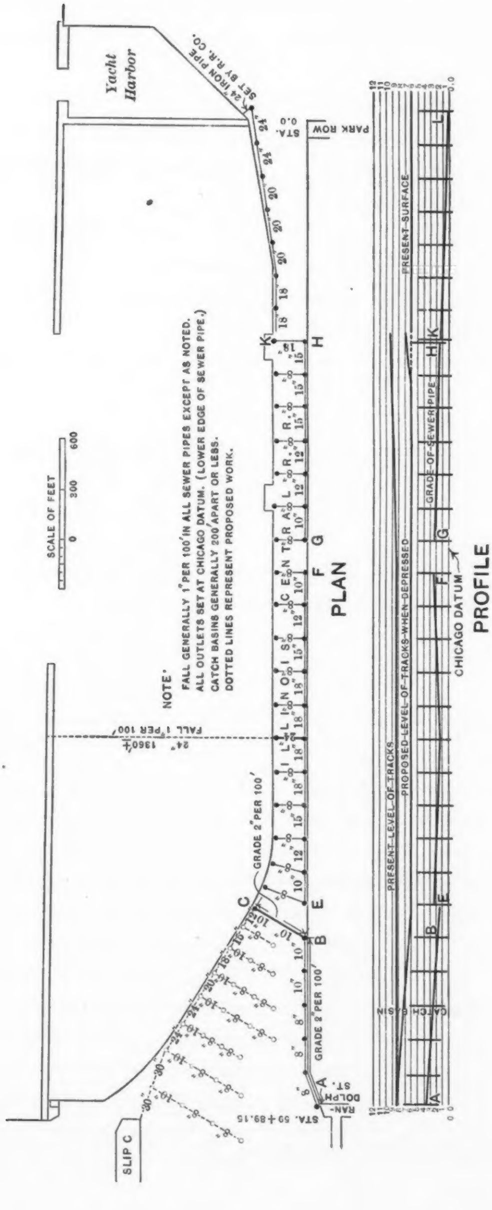

Yacht Harbor
24" IRON PIPE SET BY R.R. CO.
PARK ROW
STA. 0.0
SCALE OF FEET
0 300 600
NOTE:
FALL GENERALLY 1" PER 100' IN ALL SEWER PIPES EXCEPT AS NOTED.
ALL OUTLETS SET AT CHICAGO DATUM. (LOWER EDGE OF SEWER PIPE.)
CATCH BASINS GENERALLY 200' APART OR LESS.
DOTTED LINES REPRESENT PROPOSED WORK.
ILLINOIS CENTRAL R.R.
FALL 1" PER 100'
24" 1360'±
GRADE 2" PER 100'
RAN-DOLPH ST.
STA. 50+89.15
SLIP C
PLAN
PRESENT-SURFACE
PRESENT-LEVEL-OF-TRACKS
PROPOSED-LEVEL-OF-TRACKS-WHEN-DEPRESSED
GRADE-OF-SEWER-PIPE
CATCH BASIN
CHICAGO DATUM
PROFILE

FIG. 6.

buildings, was responsible for the construction of the Van Buren Street Station and the design and construction of the retaining wall, sea wall and viaducts.

Mr. H. U. Wallace, resident engineer, had personal and direct supervision of the execution of the entire work on the ground.

Mr. F. T. Bacon, architect, made the designs and detail plans of the Van Buren Street Station.

Mr. G. F. Jenkins, master carpenter, acted as superintendent of construction of the Van Buren Street Station.

The inspection of the steel work of the viaducts was performed by John Lundie, M. Am. Soc. C. E.

1897. AUGUST. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

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THEORY AND PRACTICE OF SPECIAL ASSESSMENTS.

BY J. L. VAN ORNUM, ASSOC. M. AM. SOC. C. E.

TO BE PRESENTED SEPTEMBER 15TH, 1897.

CLASSIFICATION AND HISTORY.

Taxation has been the most potent factor in the history of nations. It remains the most powerful influence in governmental functions of the present. The justness of the system and of its apportionment are fundamental necessities in both national and municipal government. Adequate, equable and just methods in taxation may, at times, seem hardly realized, especially under the charter restrictions, local usage and the condition of municipal finances in some cities; but correct principles will be the aim and the tendency in any system that holds the confidence and support of the citizens.

Omitting gifts and income from quasi-private business undertakings, both of which are of little moment in this nation, revenue is derived from compulsory contribution under the process of eminent domain, penalties, fees and taxes. Under the power of eminent do-

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

main private property is taken for public uses, but its value is paid to the owner, resulting in only an incidental revenue, if it exists at all. Penalties and fines are imposed under the penal power primarily for punishment, but revenue results. Fees arise under the police power and consist of an enforced payment to cover, in whole or in part, the expense of each act or special service rendered. A tax is an enforced contribution by all the interests affected, levied by the authority of the state for the maintenance of the institutions and interests of the government and without reference to the particular benefits conferred. Taxes may be either general or special, as the object is for the general interest or for the advantage of a certain portion or district. It is sometimes difficult to distinguish between fees and taxes, but the underlying purpose in each case will generally decide. The police power is exercised primarily for the purpose of regulation, the idea of revenue being incidental; while taxation has revenue as its object, with special advantages (when they occur) as incidental. Adam Smith distinguished the former as particular contributions, and the latter as general contributions. The one is apportioned according to the privileges or benefits received, the other to the ability to pay.

Under which head shall special assessments be classed? Local assessments in some characteristics invade the domain of both the police power and the taxing power, and in the early days of its growth it was the practice to assess such charges under the one power or the other as circumstances seemed to make the more advantageous. Especially have special assessments and special taxes appeared sometimes to merge, as here the distinction between a local and a general application is lost.

The distinctively American principle of special assessments has been a growth occasioned by public necessities and common justice, sanctioned by statutes, interpreted by judicial decrees, and firmly established in the economics of the republic. By reference to the Appendix, where the law of special assessments is treated at length, and to the following paragraphs, it will be seen that the correct principle and almost universal practice is to include them under the general taxing power, and yet consider them to differ from taxes in general to an extent that holds them not in violation of constitutional requirements providing that taxation shall be equal and uniform. Local assessments belong to the taxing power because they are primarily for rais-

ing revenue, and they must be for public purposes, capable of apportionment, collectible by compulsory process, and not arbitrary in effect. They differ from taxes, special and general, in the fact that a real benefit to the contributor is conferred, which is the measure of liability to be taxed, and this is not true of taxes. They are distinct from fees in that they are restricted to a particular object, district and time, and their purpose is revenue, and not regulation or special privilege. It would be hardly necessary to distinguish special assessments from expropriation under the power of eminent domain, except that there sometimes arises a confusion of two distinct processes. In the prosecution of a public project, the land that is required is secured directly by expropriation; but the exercise of the power of eminent domain stops here, and the improvement is effected and its cost apportioned under the wholly distinct process of local assessment.

A special assessment may, then, be defined as "a compulsory contribution paid once and for all to defray the cost of a specific improvement to property, undertaken in the public interest, and levied by the government in proportion to the special benefits accruing to the property owners."*

The history of special assessments covers more than two centuries. Of continental Europe only Belgium and Germany have applied the principle to any considerable extent, the former having made use of the system during the greater part of this century, and the latter having employed it for a score of years, principally in the construction of streets.. However, there is this distinction in principle between the continental and the American systems; while in this country it is levied under the taxing power, in Europe it is considered an exercise of the police power, which there includes, not only the regulation of the acts and conduct of the people in the interest of the general safety, health, morals, order and justice, as in the United States, but is extended in scope to include also the power to secure general advantages and public improvements. Great Britain has enacted such laws on three different occasions, but none are now in force. The most marked of these laws was that passed in 1667 to regulate the rebuilding of London after the great fire of the year preceding, thus making it the first law ever enacted which conformed closely in principle to our present laws. It is also interesting as forming the model upon which the first American law was framed.

* E. R. A. Seligman, *Quarterly Journal of Economics*, April, 1893.

In America, the Colony of New York first enacted a true special assessment law for New York City, the date being 1691. A literal copy of the pertinent portions of this act follows:*

"An Act for the Regulating the Buildings, Streets, Lanes, Wharffs, Docks and Allyes of the City of New-York."

"Whereas the City of New-York, and Metropolis of this Province, was chiefly erected by the Inhabitants thereof for the propogating and encouragement of Trade and Commerce, and for the good, benefit and welfare of their Majesties Subjects inhabiting within this Province. And forasmuch as it is very necessary for Traffick and Commerce, that Buildings, Streets, Lanes, Wharffs, Docks and Allyes of the said City be conveniently regulated with Uniformity, for the accommodation of Habitations, Shipping, Trade and Commerce, and that all Impediments and Obstructions that may retard so necessary a Work, may be removed, Be it Enacted by the Commander in Chief and Council, and Representatives met in general Assembly, and by the Authority of the same, That the Mayor, Aldermen and Common-Council of the said City, shall and may, at their will and pleasure,

* * * * * * *

"And forasmuch as the Filth and Soil of the said City, lying in the publick Streets thereof, doth often prove a common Nusance unto the Inhabitants and Traders to and from the said City, and very prejudicial to their Health; For the Removal thereof, Be it further Enacted, &c., That the Numbers and places for all common Severs, Drains and Vaults, and the Order and manner of Paving and Pitching the Streets, Lanes & Allyes of the said City, shall be designed and set out by the Mayor, Aldermen and Common Council of the said City, together with the said Surveyors or Supervisors appointed in manner aforesaid; and when they assemble, shall have Power and Authority to order and direct the making of Vaults, Drains and Severs, or to cut into any Drain or Sever already made, and for the altering, enlarging, amending, cleansing and scouring of any Vaults, Sinks or common severs. And for the better effecting thereof, it shall and may be lawful to and for the said Mayor, Aldermen & Common Council, together with the Surveyors and Supervisors, at their said Meeting, to impose any reasonable Tax upon all Houses within the said city, in proportion to the benefit they shall receive thereby, for and towards the making, cutting, altering, enlarging, amending, cleansing and scouring all and singular the said Vaults, Drains, Severs, Pavements and Pitching aforesaid. And in default of payment of the said sum to be charged, it shall and may be lawful to and for the said Mayor and Aldermen, Etc., so authorized, as aforesaid, by Order or Warrant under their Hands and Seals, to levy the said sum and sums of Money

* From Bradford's "The Laws of Her Majesty's Colony of New York," etc., p. 9.

so assessed, by distress and sale of the Goods of the Parties chargeable therewith, and refusing or neglecting to pay the same, rendring the over-plus, if any be."

This law, just quoted, involved the essential principles of special assessments, as it plainly applied to street pavements and to sewers the principle of assessing the cost of public improvement, by a special procedure, upon the property interested in proportion to the benefits received, forcing the payment, if necessary, in the manner customary with general taxes.

The next similar law enacted in this country was a province law of Pennsylvania of the year 1700. This provided that "to defray the charge of pitching, paving, gravelling and regulation of said streets * * * each inhabitant was to pay in proportion to the number of feet of his lots * * * adjoining, on each or either side of the said streets."*

The only remaining province which promulgated similar laws before the formation of the republic was Massachusetts. During the reigns of Queen Anne and George III, "persons receiving any benefit from common sewers, either direct or remote, were obliged to pay such proportional part of making or repairing the same as should be assessed to them by the selectmen of the towns.† These acts are dated 1709 and 1761.

At the close of the Revolution, laws of a similar nature were reenacted, generally with more definite provisions, by the three commonwealths. By a statute passed in 1781, in that part of Charlestown, Mass., laid waste by fire by the British troops, the improvement of streets was paid for by assessment on property benefited; other similar laws followed. The old New York law seems to have remained in force, though little used, until 1787, when it was amended and made more definite.‡ Pennsylvania at this period inclined to move backward from the theory, as the cost of improvement was made payable by taxation and not on the principle of assessment according to benefits. Again, about the time of the war of 1812 there are clustered some further provisions of a similar nature. Several suburbs of Philadelphia applied the principle at this time,§ and in New York the cities of New York, Albany, Schenectady and Hudson were authorized to

* Cited in 65 Pa. St., 158.

† Cited by Chief Justice Bigelow in 94 Mass., 239 (All. 12).

‡ Chapter 88 of the 10th Session, Laws of New York, p. 544.

§ 65 Pa. St., p. 160, etc.

make use of the system in 1813, Troy in 1816, Utica in 1817, and other towns seem to have had the same power given them at this time, though in less definite language.*

Following the example of the enactments mentioned, and encouraged and stimulated by their application in the instances given, the principle of special assessments began to be adopted quite extensively and thoroughly, resulting in a steady growth and an increasing application throughout the present century. The following dates may be taken as indicating about the time when the system became adopted in the policies of the different states and territories;† these dates usually mark a real application of the principle in the charter of some city, followed generally by court decisions in the main upholding the method, and by a substantial and continuous development of the system in other portions of the commonwealth in question.

The principle may, then, be considered as dating, in New York from 1813; Kentucky, from 1813; Michigan, 1827; Pennsylvania, 1832; Louisiana, 1832; New Jersey, 1836; Ohio, 1836; Illinois, 1837; Maryland, 1838; Connecticut, 1843; Wisconsin, 1846; Indiana, 1846; Mississippi, 1846; California, 1850; Oregon, 1851; Missouri, 1853; Rhode Island, 1854; Iowa, 1855; Delaware, 1857; Kansas, 1864; Massachusetts, 1865; District of Columbia, 1865; Virginia, 1866; Vermont, 1868; West Virginia, 1868; Minnesota, 1869; New Hampshire, 1870; Texas, 1871; Maine, 1872; Nebraska, 1873; Florida, 1877; Georgia, 1881; Nevada, 1881; Washington, 1883; Alabama, 1885; North Carolina, 1887; North Dakota, 1887; South Dakota, 1887; Montana, 1887; Idaho, 1887; Wyoming, 1887; Utah, 1888; Colorado, 1889; Oklahoma T., 1890; New Mexico T., 1891; Arizona T., 1893; and South Carolina seems now prepared to return to the favorable attitude she held in the first half of this country (though this policy was afterward reversed), as the new state constitution (1895), recognizes the "power of cities and towns to levy taxes and assessments * * * and no tax or assessment shall be levied or debt contracted except in pursuance of law, for public purposes specified by law." As yet the general assembly of South Carolina has passed no act declaring the exact scope of this provision.

* See Laws of New York, 1813-1818.

† The greater part of these dates are taken from the extensive monograph of Victor Rosewater, in Vol. ii of the Columbia College "Studies in History, Economics and Public Law" (1893), to which the author is also indebted for many of the references in this historical résumé.

There remain only two, from among the states and territories of the republic, whose settled policy continues adverse, Arkansas accepting the principle only partially, and Tennessee not at all.

Arkansas considers special assessments as under the taxing power, but the state constitution of 1874 provides that such assessments must be preceded by "the consent of a majority in value of the property-holders owning property adjoining the locality to be affected; but such assessments shall be *ad valorem* and uniform." As this substitutes for the principle of assessment according to benefit the method of according to value, it departs to this extent from the true principle of special assessments, and conforms more to the idea of a special tax. Following this idea statutes were enacted in 1881 under which improvements have been made and their cost assessed within "improvement districts" according to the principle given.

In Tennessee the Supreme Court in 1872 declared special assessments absolutely void because in violation of the provisions of the state constitution of 1870, which provides that all state, county and municipal taxes shall be equal, uniform, and according to value. These specify the sole rule by which a tax can be imposed, and the "spirit of the constitution imperatively demands that it be observed in all cases."* There is an exception made in favor of assessments that clearly and unmistakably can be levied under the police power, especially sidewalks, but so completely has this decision affected the policy of the state, that the only provision for municipal improvements in later laws (especially those of 1883) allows the raising of the necessary funds only by general taxation, for such works as paving, sewers, water-works, etc.

Present Practice in Fifty Cities.

During the early part of the present year information was furnished by officials of the following cities, giving their actual methods of making special assessments. To the city engineers and other officials through whose courtesy this data has been secured, acknowledgment is here given of the value which such facts furnish to an extended discussion of this subject. It was the endeavor to select these municipalities so as to make the methods, as illustrated by them, representative of American practice; and therefore they were chosen to secure

* Freeman, J., in 9 Heisk, 349.

as complete a geographical distribution as possible, besides including smaller cities as well as the larger and more important ones. While special assessments usually are levied for the construction of sidewalks and curbing (but sometimes under the distinct authority of the police power), and while the cost of bridges, street lighting, the maintenance and repair of public improvements, and other such expenses, are sometimes so assessed (although the customary way is to charge them to the city), yet it has been deemed sufficient for this investigation that it should cover only the more usual and important subjects of assessment, that is, pavements (including foundations and grading for the paving), sewers, and water-works; the question of assessing the expense of street sprinkling, now growing in importance, is also covered, as well as that of limiting the total amount that can be levied to a certain percentage of the tax valuation of the property. The following list is arranged according to the geographical location of the cities replying.

Portland, Me., lays the total cost of all street improvements upon the city. Its water-works were constructed and are still owned by a private company, thus escaping the question of direct special assessment. Its sewer system is constructed by placing the expense of the main sewers upon the city, together with one-third the cost of the laterals, while two-thirds of the cost of the latter is assessed on lots benefited, in proportion to area. Street sprinkling is done by private arrangement, the rate being about 10 cents per front foot.

Manchester, N. H.—In this city the total cost of all public improvements is paid by the city, the only partial returns for the same being the water rates charged those using the city water, and a charge for sewer entries of 30 cents per front foot on all streets except one, where the charge is 50 cents per front foot. The street sprinkling, even, is done at the expense of the city.

Lowell, Mass., requires a street to be graded satisfactorily to the council at private expense before it will be accepted by the city as a public thoroughfare; all subsequent improvements are paid for by the city. The established water rates are the only individual charge for water-works. For lateral sewers the abutting property pays one-half the cost, or less, the city bearing the remainder. Where a main sewer is laid in a street the abutters are assessed on the basis of what would be the amount on a lateral sewer instead. The cost of street sprink-

ling, which is done by the city, is assessed upon the frontage, amounting to about 4, 5 and 6 cents per linear foot on streets 40, 50 and 60 ft. in width.

Springfield, Mass., effects all street improvements by general taxation. The water-works were similarly constructed, the water rates apparently being devoted to maintenance. The sewers were also built at the city's expense, but there are certain charges for connection which, in the case of stores and manufactories, amount to $1.50 per front foot. One-half of the cost of sprinkling is paid by the city and one-half by abutting property according to frontage.

Worcester, Mass.—The city assesses the cost of grading on property generally by the frontage rule, but at times by area. Paving and repaving is charged to the city. Its water-works system was also built by the city at its own expense. The property benefited bears three-fourths the cost of lateral sewers, and the city the balance. Where a main sewer occurs, the property pays what would be charged if it were a lateral, and the city the remainder. For sprinkling the streets the city gives the water and assesses the cost of distribution. Assessments are not limited to a certain percentage of the tax valuation of the property.

Providence, R. I., accepts streets only when they are brought to grade by the previous owners. All street improvements are made at the expense of the city. Concerning the water-works, rates are charged the consumers sufficient not only for maintenance and the necessary extension, but also to provide for the sinking funds for the cost of construction. Examples of the rates charged are: For one faucet, $6; bath-tub, $5; water-closet, $5; and set basin, $2 per year. For the sewer system, property benefited pays 60 cents per linear foot frontage, and 1 cent per square foot of area, the city paying the remainder. It is estimated that this method charges the property with 50 to 60% of the cost of the entire system. Street sprinkling is entirely by private arrangement.

Hartford, Conn., grades its streets at the expense of the city. Subsequent improvements are charged, two-thirds upon abutting property according to its linear frontage, and one-third upon the city. Repairs are made under five-year guaranty by the contractor; otherwise by the city. Water-works were also built at the public expense, rates to consumers now covering the ordinary expenses. Intercepting sewers

have been built at the city's expense, but of the general sewer system itself the total cost of any main with its laterals is "assessed pro rata upon the property benefited, by the front foot," corner lots paying only for one front. Sprinkling is done by private contract. There is no limit fixed by requiring special assessments not to exceed a certain ratio of the tax valuation of the lots affected.

New Haven, Conn.—Here the grading is done by the city. For street improvements the property abutting pays for 1 sq. yd. for each running foot of front, if there has been no previous assessment for similar work; but if it is a renewal, the cost of $3\frac{1}{2}$ sq. ft. is similarly assessed. The water-works are owned by a private corporation. For the sewers the general rule has been followed of assessing at the rate of $1 45 per front foot. This rule, formulated when the system was devised in 1872, was so fixed under the expectation that, when the system shall be entirely completed, it will result in placing one-third the cost on the city and two-thirds on the adjoining property. Street sprinkling is assessed against the lots affected by linear frontage.

Albany, N. Y., places the cost of grading for street improvements entirely upon contiguous property, but by an elastic rule permits the Board of Contract and Apportionment to vary the distribution between the "frontage" rule and the "area" rule, as seems most just in any case. Unlike most New England cities, the abutting property pays for paving in proportion to its frontage usually, yet here also there is some elasticity allowed, permitting other methods if deemed more fair. The city pays no proportion except for city property abutting. Street intersections are assessed on the street and on lateral streets for half the depth of the blocks. Allowances are made for corner lots. For repaving the same method is followed as for the original work if half the frontage affected petitions for some different kind of pavement; otherwise, the city bears the expense. The charter compels the paving contractor to repair for from five to fifteen years. Concerning the water-works system the only private charge, except the water rents (amounting to 8 cents per 1 000 galls. where meters are used), is an assessment to pay partially for the extension of the distributing system to localities which previously had no supply, thus charging such property to an extent which will at least partially compensate for its previously escaping all water rents; in this category have occurred some distributing mains which the water commissioners attempted to pay

for with city bonds, but were prevented. In the consideration of the sewer system the same latitude of action is allowed the Board of Contract and Apportionment as before, the purpose being to secure assessments in proportion to benefits, but the result being assessment according to no fixed rule but variation in method according to circumstances in each case, the frontage method and the area rule have both been used. The most of the sprinkling is by private contract.

Brooklyn, N. Y.—In this city grading and paving are usually assessed on property contiguous, 60% of the total being apportioned on property abutting in proportion to frontage, and 40% on property within the district (usually one-half block each side of the improved street) according to area. Repaving is paid for, one-half by the city and one-half by property, according to frontage, unless the street carries a street railway, in which case one-fourth of the total expense (which forms the railway's portion) is deducted from the burden on the property, thus reducing its proportion to one-fourth the total. The water-works supply system and mains are constructed and laid at the city's expense, while the laterals are charged on property by the frontage rule. The water revenue (the rates may be judged from the meter charge of $7\frac{1}{2}$ cents per 100 cu. ft.) provides for maintenance, interest on water bonds, and a certain percentage of the debt through the sinking fund. The cost of the sewer system is entirely charged to property benefited according to area, except for reconstruction or for special relief sewers, for which the city pays. Street sprinkling is by private contract. There is no percentage limit to the amount that may be assessed on property, reckoned on its tax valuation.

Buffalo, N. Y.—This city places the cost of grading, paving and the renewal of pavements all on abutting property in proportion to frontage; and maintenance, when it requires the replacing of one-third the pavement or more, becomes a renewal. The water-works system was built and is extended by the city. The main sewers are built at the expense of property, a varying percentage being assessed by frontage and the balance over all the area tributary. The laterals are built from the proceeds of a frontage assessment. However, some intercepting sewers have been entirely at the expense of the city. Street sprinkling is assessed on property by the frontage rule.

New York City levies assessments for public improvements through a Board of Assessors, in whose province lies the determination of the

particular method by which the assessment is apportioned. Nevertheless it is the common practice to assess the cost of grading and paving upon abutting property in proportion to its frontage. The cost of renewal is usually a general charge upon the city. There are no local assessments to pay for any part of the water-works system. The revenue derived from private person is through the established water rents. All sewers are "paid for by owners of all the property intended to be benefited thereby." Any real estate owned by the city pays for public improvements the same as though it were under private ownership. The sprinkling and cleaning of streets is paid for out of funds raised by general taxation. No property can be assessed, for any one improvement, more than one-half of its tax valuation.

Rochester, N. Y., assesses the cost of all street improvement upon abutting property according to its frontage ratio. The water-works system is paid for by the city. In the sewer system the mains are constructed at the expense of property, partly by frontage and partly by an area charge, while the laterals are built wholly by a frontage assessment. Street sprinkling is made a frontage charge. There is no limit to the amount of an assessment fixed as a percentage of tax valuation.

Syracuse, N. Y.—Here the charter provides for assessments according to benefits, thus allowing the assessors considerable latitude. The usual practice, however, is as follows: The cost of all grading, paving and renewal is placed upon abutting property by the frontage rule; but allowances are sometimes made when this would work injustice, as in the case of an extremely shallow lot or a corner lot. The water-works system is a charge upon the city, with no personal charge except the established water rates to consumers, and no assessment upon property except an annual tax of 5 cents per lineal foot of front (corner lots paying only for their shorter front and for the other in excess of 8 rods), which is rebated upon the rates charged the owner of the same property for the use of water, but not to exceed such rates. The cost of all sewers is assessed upon property fronting upon them according to linear extent, except where the sewer exceeds 2 ft. in diameter; in this case, all expense in excess of what a 2-ft. sewer would cost is borne by all the property in its established drainage area, distributed according to the area rule. Street sprinkling is assessed upon property according to its frontage; and in this city, again, the assessment is not

limited to a certain percentage of the tax valuation of the property affected.

Newark, N. J.—Here the grading, curbing and paving are done at the expense of abutting property, and the levy is made by the frontage method, street intersections being included in this levy, and city property abutting being assessed as though it were private. On corner lots, where the long side fronts on the improvement, it is the custom to assess only 65% of the regular frontage rate. Renewal is made a charge also on abutting property. The water-works were built by the city at its expense. Of the sewer system, both mains and laterals are a charge upon abutting property, except where a main sewer is laid the property is charged only with the cost that a pipe sewer would have in the same place. Street sprinkling is by private arrangement.

Paterson, N. J., places the cost of grading and paving upon property fronting, by linear proportion. Repaving is at the expense of the city. A private corporation owns the water-works. A certain latitude in the method of making sewer assessments "for actual benefits to property" seems to hold, for in the case of main sewers a certain proportion is paid for by property and the balance by the city, while laterals are assessed "by commissioners on abutting property, each lot being assessed in addition for privilege of connection. In this manner city is reimbursed for its outlay on mains." Sprinkling is done by appropriation from the general tax levy.

Harrisburg, Pa., in the public improvements which it actually constructs, lays the cost of paving, and generally of grading, upon abutting lots by the front foot rule. For water-works construction there is a fixed rate placed upon abutting real estate, amounting to 80 cents per foot front for 6-in. pipe, 90 cents for 8-in., and $1 per foot for all larger sizes; in the case of a corner lot, one-third is taken off the charge for the longer side. The sewers are all built at the expense of property benefited. The cost of laterals and a portion of the cost of main sewers (as much as a lateral would cost) is charged to abutting property, the district as a whole taking the balance. The renewal of any kind of improvement can never be assessed upon private property.

Philadelphia, Pa.—The city assesses the cost of original paving upon abutting property, while grading is a city expense. Renewal is also a general charge. For the construction of the water-works distrib-

uting system there is a fixed charge of $1 for each foot fronting on any street where pipe is laid, but city property pays no part of this frontage charge. The supply system in general is maintained and extended from the revenue derived from water rates, the charges of which may be judged from the meter price of 30 cents per 1 000 cu. ft. For the sewers there is a fixed charge of $1 50 per front foot on property abutting, whatever be the size of the sewer, any additional cost being paid by the city. In the case of corner lots with sewers on both fronts there is made a deduction of one-third the longer front, such deduction not to exceed 50 ft. There is, besides, a special charge of $5 for every connection with the sewer in addition to the usual permit charge. These sewer assessment bills are assigned to the contractor in part payment for the work, giving him a lien on the property and the right to collect in the name of the city. The city sprinkles macadamized streets at its own expense.

Scranton, Pa., charges abutting property for grading by the foot front rule, "after getting a release from each and every property owner relinquishing all claims for damages in consequence of grading." Paving is also assessed by linear frontage, and kept in repair for five years by the contractor. Renewals are charged, generally, one-half on abutting property and one-half on the city. The water-works are owned by private corporations. Lateral sewers are usually assessed on adjoining property according to its linear frontage, and the main sewers upon the property in the drainage district, by a specially appointed board of viewers, "according to benefits." Street sprinkling is secured by private arrangement. The amount of an assessment against private property is not limited to a percentage of its tax valuation.

Wilmington, Del.—In this city all street improvements are paid for by the city. The water-works are owned by the city, and are now a source of revenue. Apparently the only charge to the public is from the water rents, the rates of which may be inferred from the meter charge of 75 cents per 1 000 cu. ft., with reductions for large quantities. Adjoining property is assessed for the sewer system at the rate of 50 cents per front foot and 1 cent per square foot of area for a distance not exceeding 150 ft. back from the building line. This charge is supposed to represent three-fifths the total cost of the sewers, the remainder being a city expense.

Baltimore, Md., places the cost of grading and paving upon abutting property in proportion to frontage. The city escapes the expense of repairs to pavements for two years by contracting with the persons laying the pavement to keep it in repair for that length of time. There are no assessments made for water-works construction and extension. Although the city charter permits it to assess the cost of sewer construction upon property benefited by the area rule, yet for the past five or six years this has been paid for entirely by the city. Sprinkling is by private arrangement.

Washington, D. C., pays for all street improvements out of the general fund. Concerning the water-works, the large supply mains are constructed from the general fund, but for the distributing system there is an assessment upon all abutting lots or land of $1 25 per linear front foot; corner lots do not pay on their longer front unless it exceeds 100 ft. The cost of the main sewers is also defrayed from the general fund; for the branch or lateral sewers built, one-half the cost is paid by abutting property according to its linear frontage, and one-half from the general fund. The cost of sidewalks and curbing follows the rule last given, which is rare for these improvements. Street sprinkling is charged to the general fund.

Richmond, Va., makes all street improvements at the general expense. There is no private charge for the water-works system (which is owned by the city) except the usual requirement that connection be made at the property owner's expense. Of course, the universal water rent charge is placed upon all consumers. The entire sewer system was built by the city, for which property is assessed "annually at the rate of 10 cents per front foot of property, or a commutation tax of $1 50 per front foot." As usual, the cost of house connections is borne by those making them. Sprinkling is done by private arrangement. An unusual undertaking is the owning and operation of the gas works by the city, furnishing consumers with gas at the rate of $1 per 1 000 cu. ft.

Charleston, S. C., makes all public improvements at the expense of the city. The water-works are owned by a private company.

Atlanta, Ga.—In this city the grading is a city expense, but all other street improvement is effected by placing two-thirds the cost on abutting property in proportion to its frontage, and the remaining one-third upon the city. The entire water-works system is constructed

without special assessments. Main sewers were built by the city, but for branches and laterals there is a uniform charge of 90 cents per lineal foot front on abutting lots or lands, except where a corner lot has already been assessed for one front, in which case 75 ft. of the second front is exempted. Street sprinkling is done by private arrangement.

Augusta, Ga.—Here the only assessments charged upon property are for pavements and sewers, for both of which property fronting upon the improvement pays half the cost, distributed in proportion to its linear frontage.

Jacksonville, Fla., pays one-third the cost of all street improvements, the abutting property paying the remaining two-thirds in proportion to linear frontage. The water-works and sewer systems are paid for by the city. An assessment is not limited to a percentage of the tax valuation of the property.

Montgomery, Ala., charges one-half the cost of all street work against abutting property owners, and one-half is paid by the city. The water-works are not owned by the city. The sewer system is entirely a city expense. Street sprinkling is also a public charge. The city charter fixes the maximum limit of an assessment at $10 per front foot.

Nashville, Tenn.—Here all the usual public improvements are constructed and extended at the expense of the city. No special assessments are levied.*

Louisville, Ky., lays the total cost of grading and paving upon the area contiguous, usually extending for one-half block on each side of the street improved, with corner lots paying 25% more than inside lots. All renewal of pavements is made by general tax levied for the reconstruction of streets. For the construction of the city's water-works there has been no assessment, the only private charge being the water rates. The sewer system has also been constructed by the city. Street sprinkling is by private arrangement. There is no limit to the amount of assessment fixed at a certain percentage of the tax valuation.

Cincinnati, O., pays 2% of original street improvements, and assesses the remainder upon abutting property according to the frontage rule, but in so apportioning the assessment the city pro rates as abut-

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* Compare with paragraph on Tennessee, p. 355.

ting property for the intersections or junctions of lateral streets, as well as for any abutting lots it owns. In repaving, such work as has been done under special acts of the general assembly (aggregating in value $8 000 000) has been borne, half by the city and half by abutting property; otherwise renewal has been paid for as has the original work. The water-works are a public charge. Sewers are made a charge upon adjoining property to the extent of $2 per front foot, the balance being paid by the city. No assessments are made for street sprinkling. Property petitioning for an improvement may be assessed its full value; but when not petitioning it can be assessed only to the limit of 25% of its value.

Dayton, O., assesses the cost of all street improvements upon abutting property by linear frontage, except that the city pays for street and alley intersections. The contractor maintains the pavement laid by him for five years after its construction, after which it is repaired at the expense of the city, as is the usual rule. The water-works system is a general charge; except that, of course, property has to pay for the house connections. The storm-water sewers are built by the city, but the cost of sanitary sewers is assessed upon property benefited, usually by the abutting foot. Street sprinkling is assessed upon abutting property in proportion to its frontage. The limit of assessment for sewers is $2 per foot; on other improvements, 25% of the tax valuation.

Indianapolis, Ind.—In this city all street improvements are assessed upon lots or lands abutting on the street, in proportion to linear frontage; except that one-half the cost of street and alley intersections in any case is assessed upon property fronting on the intersecting street or alley for a distance up to the next street encountered; for city lots the municipality is liable as other property holders are. The city contracts with the Indianapolis Water-Works Company for its water. The cost of local sewers is assessed upon abutting property in proportion to area, unplatted land being considered to have a depth not less than that of adjoining lots nor greater than 200 ft. City lots bear their due proportion. For main sewers, such part of their cost as would construct a local sewer in the same place is apportioned upon abutting property by the method given for local sewers. The balance is distributed over all the lands included in the district drained "in the proportion its area bears to the total area of the district, in-

cluding abutting property holders, as well as the holders not situated on the line of such drain or sewer." The city pays no part of the expense, except as an owner of property. The cost of street sprinkling is charged to abutting property by linear ratio.

Peoria, Ill., charges the contiguous property with the total expense of all street improvements, basing the rate on linear frontage. Asphalt pavements are guaranteed by the contractor for a period of five years. The water-works are owned by a private company. The cost of the sewer mains and laterals, in any district, is considered jointly, and the entire amount is assessed upon the property benefited according to the area rule. While the city is not required to pay any portion, it has been its general custom to pay a certain percentage of the cost where large mains are constructed, so as to relieve the lots and lands from burdensome assessments. The sprinkling is done by private arrangement.

Detroit, Mich., pays the cost of grading and paving the street and alley intersections, but all the balance is assessed upon abutting property by the linear method. The expense of repaving is carried by the city. The outlay for the water-works is borne wholly by the water rates charged consumers. In the sewer system the mains are constructed by the city, and the cost of the laterals is assessed upon adjoining property in proportion to frontage. Street sprinkling is controlled by private contract.

Milwaukee, Wis., charges adjoining property with the expense of grading and paving, except the cost of street and alley intersections, which falls to the city. Repaving is done at the expense of the ward unless the renewal involves a pavement with a concrete foundation, in which case the expense is borne as in the case of an original work; however, under such circumstances, the property affected is credited with the cost of the original pavement. In the water-works system half the cost of laying a 6-in. main is charged against the property on each side of the street, corner lots receiving a deduction of one-third their lateral frontage. The balance is paid from the water fund, which is created by the revenue of the water department, excluding the supply system for the construction of which city bonds have been issued. For the sewer system the property on each side pays one-half the cost, providing this does not exceed 80 cents per foot. Corner lots are allowed a deduction of one-third their total frontage. The sewerage

district pays the balance. Street sprinkling in central wards is paid for by the ward fund (raised by general taxation on all property in the ward). In outlying wards this expense is assessed upon abutting property by the frontage rule, the ward fund, however, being drawn upon for the portion chargeable to the street and alley intersections. In this city the assessments cannot exceed the tax valuation of the property, which is two-thirds its actual value.

Minneapolis, Minn.—In this city grading is done at the expense of the ward. The city pays for paving and repaving street intersections, and the remainder is assessed upon abutting property by linear frontage. The contractor for an asphalt pavement agrees to keep it in repair for ten years after the date of the acceptance of the work by the city. For water mains abutting property is assessed a fixed amount of 65 cents per foot front, this being considered the cost of a 6-in. main. All other expense for the water-works system falls directly upon the city. For the sewer system there is a similar fixed charge upon abutting property, amounting to $1 50 per front foot, the estimated cost of a 15-in. sewer, all additional expense being borne by the city. The street sprinkling is done under the direction of ward officers and its cost assessed upon adjoining property in proportion to frontage.

St. Paul, Minn., assesses the total cost of all street improvements upon abutting property, usually by the front foot. The water-works supply system is paid for by the city. For all pipes of the distributing system there is a frontage charge upon abutting property of 10 cents per lineal foot for a period of ten years, regardless of the size of the pipe. The balance is met by the city. The Board of Water Commissioners is required to fix the water rates so as to pay for all running expenses and minor extensions, and to provide for a sinking fund. The cost of the sewers is assessed upon adjoining property to a maximum limit of $1.75 per front foot, although the law permits larger assessments. All excess is paid by the city. The cost of street sprinkling is borne by the property in proportion to its linear frontage. There is no limit to the amount that may be assessed, fixed by a certain percentage of the property's tax valuation.

Burlington, Ia., charges grading upon the city. Brick pavements are paid for by assessment upon abutting lots, except the cost for street intersections, which the city pays. The paving of alleys is borne by contiguous lands according to area. Repaving is a charge upon

the city. The water-works system is owned by a private company. As part payment for the cost of the sewers there is a charge upon land not to exceed 1 cent per square foot for a distance not greater than 200 ft. from a sewer. Sprinkling is a city expense.

Kansas City, Mo., assesses the cost of all street improvements against the adjoining lots and lands. On those designated as business streets the property owners may choose between two or more kinds of pavement selected by the Board of Public Works, and on residence streets a majority remonstrance prevents the work. The maintenance of paving is guaranteed by the contractor for five years, without additional payment to him. The water-works system is owned by the city and is self sustaining. No assessments are levied. Sewers in general have their cost charged upon the lands included in the district, in proportion to the area, exclusive of streets and alleys. Public sewers are built at the expense of the city. Street sprinkling is effected by private arrangement. There is no specified limit to the amount that may be assessed against property, depending upon its tax valuation.

St. Louis, Mo.—This city bears the expense of grading. All other street improvements are laid at the cost of adjoining property, according to its linear frontage. City lots bear their proportional part. The contractors are given the special tax bills in payment for their work. Repairs to paving which become necessary within five years of its construction are made by the contractor. The water-works system is paid for, both in maintenance and extension, entirely from the rates collected from consumers; consequently it is no expense to the city nor to property as such. Money which had formerly been assessed against property for construction and extension has been refunded. The range of water rates may be judged from the charge of $1 per room per year for hotels, boarding-houses and tenements; $9 for a twelve-room residence, and meter rates of 30 cents per 1 000 galls., with reductions for large quantities. Of the sewer system, the public sewers, or those having no immediate relation to property, as the intercepting and trunk sewers, are paid for entirely by the city. The district sewers, comprising the lateral sewers, with their branches, and emptying into the public sewers, are paid for entirely by private property. For these the amount due is that portion of the entire cost (in any district) of the district sewers which the area of the lot or land in question bears to the total area of the district, excluding streets. There

are also private sewers, which are constructed entirely under private agreement, plans, supervision and cost, and flow by permission into the city sewers. Occasionally, where the system is adequate, such sewers are adopted by the city, in which case the parties who constructed them are reimbursed by the city. Street sprinkling is made a charge upon property by linear frontage, the city paying the contractors in each of the fifty-four districts and collecting the tax bills itself, usually with the general tax. The cost varies from 2½ to 3 cents per front foot. The amount assessed against property for any one improvement under a single ordinance cannot exceed 25% of its tax valuation. The city bears all excess.

Little Rock, Ark.—At this place all public improvements constructed in the city are paid for by assessment upon all taxable property within the "improved district" in each case established in proportion to the value of the property.* The water-works system is owned by a private company. Statute provides that an assessment cannot exceed 20% of the tax valuation of the property affected.

New Orleans, La., assesses upon abutting property, by the frontage rule, three-fourths the cost of all street improvements and bears the remaining portion itself. For avenues having neutral ground the proportion is changed to two-thirds upon the property and one-third upon the city. The contractors are to keep the pavement in repair for a specified time, varying from one to twenty years. The water-works are owned by a private company. There is no sewer system for the city. Street sprinkling is done by those contracting for maintenance of pavements, and by the city after the expiration of such contracts. The amount of an assessment is not limited to a percentage of the tax valuation.

Sioux Falls, S. Dak., assesses the cost of all street improvements upon abutting property, except that of street intersections, which the city pays. The water-works are owned and operated by a private corporation. For all sewer construction there is a fixed charge of $2 30 per front foot upon business property, and half this amount upon residence property. The city pays for sprinkling the streets.

Omaha, Neb., pays half the expense of grading. The remainder is assessed upon property by linear frontage. If three-fifths of the property holders petition for the grading, all the expense is charged upon them. Subsequent street improvements are all assessed upon abutting

* Compare with paragraph on *Arkansas*, p. 355.

property in proportion to extent of frontage. The city, however, pays for intersections. The water-works system is under private ownership. Main sewers are built by the city. The cost of the laterals is assessed upon adjoining property by linear frontage. Street sprinkling is a private expense. Tax valuation does not form a basis for fixing a limit to the amount of an assessment.

Topeka, Kan., charges the city with the expense of grading. The cost of paving is assessed, by a very elastic system, upon property benefited in proportions determined by appraisers appointed especially for the purpose. A water-works company holds a franchise until 1901. All sewers are also constructed at the expense of property, the cost being apportioned as before given for pavements. Street sprinkling is by private arrangement. Assessments are not limited in amount to a percentage of the tax valuation.

Salt Lake City, Utah, pays half the cost of grading the abutters' portion of the streets, and all the cost of intersections; the remainder is included in the paving assessments. Subsequent street improvements are assessed upon abutting property, according to its extent of frontage, corner lots receiving no deduction. Before distributing this assessment, the cost of intersections (which is paid by the city) is deducted, as is also (as usual) the cost of paving between and 2 ft. outside of the rails of street railways, which is a charge upon the street railway company. The pavements constructed are guaranteed by the contractor for five years, after which the contract gives the city the right to require the contractor to keep the same work in repair for an additional term of ten years at the rate of 8 cents per square yard per year. This amount is paid from the general fund of the city. The water-works supply system is paid for out of the general fund of the city, and the distributing system by assessment per front foot of abutting property, with no deduction for corner lots. Sewer mains are built at the city's expense; laterals are made a charge per front foot of abutting property, with corner lots given a deduction of 25 ft. Written objection to a proposed public improvement by the owners of half the property frontage will defeat its prosecution if filed within twenty days of the first publication of the notice that such improvement is intended. Street sprinkling is at the city's expense. There is no limit to the amount of an assessment, except, of course, the cost of the work.

Seattle, Wash.—In this city all the land, including street areas, situated between the termini of the improvement and within 120 ft. of the street-line on each side of the street improved constitutes a local improvement district, except that when a cross street has already been improved, its area is excluded. The total cost of any street improvement under consideration is then divided by the total frontage, including that of unimproved cross streets, on the improvement, and of the rate so determined 40% is assessed upon property within 30 ft. of the street lines, 25% upon property lying between lines uniformly 30 and 60 feet distant from the street, 20% upon all property between 60 and 90 ft. from the margin of the street, and 15% upon the remaining zone extending from 90 to 120 ft. in distance. "In this way it makes no difference whether a street is straight or curved or whether we turn a right-angle corner, the area included between such lines constituting the assessment area," and the zones indicating a varying percentage of charge, being always bounded by lines at the specified distance from the margin of the street. The city pays the assessment charged to street areas from the general road fund. The water-works system is a general expense upon the city. Branch sewers are constructed by assessments levied in the manner provided for street improvements; mains and intercepting sewers are constructed mainly at the expense of the city, the adjoining property paying for only what would have been the expense of a sewer suited for its needs. The total assessment levied, in any case, cannot exceed 25% of the tax valuation of the property constituting the assessment district.

Portland, Ore., assesses the cost of all street improvements upon abutting property in proportion to its frontage, except that the cost of intersections is a special charge upon the two lots nearest the corner, the corner lot being assessed for five-ninths and the one adjoining four-ninths. The contractor keeps the pavement in repair a stated number of years; afterwards this falls on the city, as usual. The water-works system was built at the expense of the city. In the sewer system, the cost of the laterals is assessed upon property fronting on the sewer, and the cost of trunk sewers is distributed over the districts drained by them in proportion to the contiguity of the property. The city pays for street sprinkling. There is no limit to the amount that may be assessed as fixed by a certain percentage of its tax valuation.

San Francisco, Cal.—Here the cost of grading and paving is made an assessment upon abutting property by the frontage rule. Repaving is paid for by the city. The water-works system is private property. The water rates are fixed by the Board of Supervisors. Main sewers are built at the expense of the district, and the cost of laterals is assessed upon property in proportion to its linear frontage. A local assessment for a public improvement cannot exceed one-half the tax valuation of the property.

Consideration of Methods and Principles.

As discussed more at length in the first part of this paper, special assessments do not properly extend to the so-called assessment of benefits and damages as employed in the condemnation of real estate for public purposes; consequently, this consideration covers only their exact field of application, that is, the assessment of the cost of municipal improvements upon property in proportion to the benefits received by it. The consideration of the levy and collection of the assessment is but indirectly important to the engineer, and is believed to be adequately treated in the first part of the Appendix and sufficiently illustrated by the Exhibit. The real discussion, then, concerns more particularly the standard methods of distributing the assessment. This question can be best judged by the principles established by the courts (given under the title "Interpretation and Judicial Decisions," in the Appendix) and by considering the actual practice of the fifty cities just given. Of course it cannot be expected that these fifty cities will illustrate all the salient facts and interesting details of methods in vogue, but it is thought that they furnish a sufficient basis for a broad interpretation of the principles involved when considered in connection with the judicial decisions mentioned, besides exhibiting many characteristic customs and peculiarities that have an individual interest.

Considered geographically, the eastern cities, as a rule, have been inclined to meet a considerable portion of the cost of their public improvements by general taxation. This fact is evidenced by a frequently occurring provision that the assessing board shall determine in each case the method to be followed in distributing the assessment upon private property; by the refusal of one state, Pennsylvania, to permit any assessment for the renewal of local improvements; by the

payment from the general fund of the larger portions of the cost, and frequently of the total expense of certain public works; and, in some cases, by the practically complete abeyance of assessment upon private property. This larger share of the general public in bearing such expenses seems to be deeply ingrained in the policies of many eastern cities, a recent indication of which is furnished by the fact that the proposed charter for Greater New York practically adopts the methods previously in vogue. Neither have the southern cities made use of the system very fully. There are notable exceptions to this general statement; but probably the past adverse economic conditions, interfering to an extent unknown elsewhere, have thus far prevented its general application.

The principle of special assessments has had its greatest development in the cities of the Northwest. This is but natural, as they have had the advantage of the earlier experiences of the older cities, and were thus enabled to profit by them. Such cities, too, have more frequently confronting them the problem of providing public buildings and general betterments, and of meeting the expense of the numerous necessities and varied functions of a rapidly growing municipality, besides constructing the usual assessable improvements, all in a short space of time; and it is to be expected that there should be an endeavor to keep the tax rate as low as circumstances would permit by making a full use of the principle of assessments for local improvements. New cities can also formulate a general plan of special assessments which will apply with great fairness and justice to all such improvements of the future, when an older city that has constructed considerable portions of its public works under inharmonious methods of accepted custom is handicapped in an attempt to secure the most just accord.

It is a quite common practice for cities to pay for the grading of streets, but it is more customary to assess the cost upon private property. By far the greater proportion of the latter class charge the total expense in proportion to linear frontage. Some assess a certain percentage, usually from one-half to three-fourths of the total, but sometimes all except the cost of street and alley intersections. Occasionally the assessment is levied partly by frontage and partly by area, and rarely it is charged entirely by the area rule. Some cities accept streets only after they have been satisfactorily graded, and other

requirements are employed by different cities to prevent the complications and suits for damages that seem inclined to swarm about improvements of this character.

In the subject of pavements there is a great diversity in methods of apportioning the cost. Of the various cities given, about 30% assess all the expense of paving on abutting property according to its linear frontage, nearly as many make it a charge upon the city alone, and the remainder divide it between the two in varying proportions. Of the latter class the favorite method seems to be to assess, by linear frontage, the total cost of the work, except the paving of street and alley intersections. Others except both intersections and the proportional charge upon city property fronting on the improvement; and in some, only the assessment upon city lots and lands is a public expense. Others divide the whole cost between the city and abutting property directly by ratio, which charges the property with a percentage varying from one-half to three-fourths of the total, the city paying the balance. A few cities incline toward the distribution of the assessment by the area rule upon lots and lands within a certain distance of the improvement, either in its entirety or in combination with the frontage method.

It is quite customary for cities to provide, by general law or in contracts with the street railway companies, that the latter shall bear the expense of paving their tracks and for a specified width outside. In such a case the portion borne by the street railway is usually deducted from the total cost and the remainder distributed between the city and private property in the prescribed way; but in Brooklyn, the street railway's portion is deducted from that part which would be assessed upon the property, the city still paying its specified percentage of the total, and so having no share in the consequent reduction in cost.

Where the city does not pay for the paving of street intersections, this expense is frequently included in the total and distributed pro rata in the general frontage. Occasionally it is made an additional charge upon lots near the corner, and in some cases it is assessed upon the frontage of the cross street for a portion of, or for the total distance to, the next street parallel to the improved one. These last methods are open to the objection that they would be likely to discourage the subsequent paving of the cross street when it is not in the

natural line of travel, a difficulty that confronts some of our cities, even if this additional burden is not imposed. Corner lots, as such, are variously treated. In some cases each margin is considered a front on its proper street, without a modification in the rate of assessment; in others, the corner has imposed upon it an additional percentage, but more frequently a certain portion of the charge upon it is abated.*

While the methods given for levying special assessments generally appear to be by some fixed and definite rule, it must be remembered that this is by no means usually so fixed by statute, but rather it is frequently a crystallization of custom, employed successively in recurring cases, under which improvements are made, and so formulated for each work under the more elastic charter provisions. Where this elasticity in the method is permitted, it generally follows the established custom and allows of modifications where necessary; but in some cases it is carried to an extreme which may give color to the charge that political influence has attempted a mitigation of the levy, and at least it prevents a general method of practice being given for the city in question. This extreme is as serious as the other which might follow from a rigid requirement, though fair and equal in general, resulting sometimes in cases of hardship and perhaps injustice to an extent that would not be permitted by the courts. On the one hand it is best that methods should be reasonably consistent and constant that property owners may know about what to expect, and the injustice of arbitrary irregularity be avoided; on the other hand there ought to occur an opportunity to vary the mode in cases where good reason exists, for the purpose of making the charge correspond to the benefits received. Concerning the question of the ratio of the cost that should be borne by the city in general, the same reasoning would have less force; and this might well be definitely fixed by charter, or general statute provision.

Although financial considerations and usage are important factors, in any case, in determining the portion of the total expense that shall be borne by the city and by property respectively, yet such factors have little importance in the abstract consideration of its most just apportionment between the two. In practice this distribution varies from one extreme, where the city pays the total cost, to the other, in which private property is charged with the entire burden. The one

* See Exhibit, Chapter VIII, Section 10.

is permissible because public improvements are considered of such general utility that their construction may be effected by general taxation, though there have been cases where this has been discouraged; and the other procedure is upheld as charging property with no greater burden than is equalized by the direct benefit to it. Both extremes have a broad sanction as not violating the lawful realm of municipal powers. If both these widely divergent methods are permissible because of the adequacy of resulting advantage in either case, it would certainly be reasonable to distribute the outlay between the two, as is done in many southern cities as well as elsewhere. Not only this, but it would seem more just and equable to divide thus, as the expense would then fall within both spheres which directly profit by the improvement, instead of the one or the other receiving a substantial benefit without sharing in its cost.

Those advocating the principle of payment by the city ignore the direct advantage, both pecuniary and utilitarian, that a good pavement secures to the property affected, an advantage sometimes augmented by the privilege given to the property owners to have a voice in the kind that shall be laid. They disregard the fact that general taxation is levied also upon personal property, the value of which is not increased by the construction of public works. They forget that the most potent factor in discouraging a demand for lavish expenditures for unnecessary improvements is making the insistent abutter pay directly for his gain, instead of bringing all the city to contribute its equal rate. Partisans of the principle of payment by the property seem to disregard the fact that the pavements are for general public use, and beneficially affect all the people and all those having business or commercial interests in the city. The claim that although paving confers a general benefit, it will become entirely compensative when all the streets are paved by assessment, will not stand, because driving and teaming naturally follow certain lines and routes which will always require the maximum of attention, leaving other streets ignored; and granting for the moment that this argument were sound, what would be gained, when every property holder has paid his part, over the method of letting every citizen pay a part constantly as the work progresses, and reaching the same aggregate in the end. Those who make the greatest use of pavements and have the largest interest in their general excellence and extent are by no means those

upon whom a corresponding charge can be fixed if linear frontage governs. To an extent the public use of the streets is proportional to property possessed, and to that extent it would seem proper that the cost of pavements should be met by general taxation, which bears upon each in proportion to his property. While nothing is proved by the fact, it may not be amiss to note that the tax rate in those cities, given as paying entirely for their public improvements, happens to be even less than is the average rate.

The rule most just and fair, then, would be to lay upon both property and municipality its portion of the cost of pavements. Private property directly profits* from its construction, the general public derives undoubted and substantial benefit as well. Let each be charged with its due proportion, as measured by the relative advantage of each. Were cities to pay from 20% to 40% of the total, individual burdens would be lighter without removing the wholesome restraint of the still remaining charge against extravagant demands, and the assessment of the remainder upon private property would free the city from too great an outlay for its needed improvements. This principle has partial recognition in many of the cities where assessment falls upon property by their assuming the cost of paving street intersections, or the portion that would attach to city property abutting, or both. This amount might well be substantially augmented in order to secure the most equal justice, and it is believed that this result will be gradually approached, and the error inhering in either extreme course, though permissible, will be finally merged into the more exact justice secured by proportioning the charge upon both interests according to the benefits received by each.

Nearly all the cities distribute the assessment upon property in the proportion that the frontage of any lot bears to the total frontage on the improvement. Exceptions to the rule are Brooklyn, Louisville and Seattle, where proportions (constant for each city, but varying for the different ones) of from two-fifths to the total amount are assessed according to the area that the lot or land (within a certain distance of the improvement) bears to the total area within the whole assessment zone or belt so formed. The width of such zone is generally fixed to include a distance on each side half-way to the next parallel street. City lots are generally so regular in size, shape and distribution that as a rule the frontage plan is quite fair in effecting

the assessment; yet there are cases where inequality will result, as where some of the abutting lots border upon the improvement with their longer side, while others so front with their shorter side. To compensate for this and similar irregularities, there is growing the commendable practice of assessing 60%, more or less, by the frontage method, and the remainder according to the area rule. This method need not be made complex or unwieldy. It lessens reason for complaint and objection, and decreases the chance of illegality in the assessment*; and if, in any case, there is absence of the irregularity in the condition of the lots that would furnish the reason for applying this system, the resulting allotment of the charge will produce the same result that would be effected if the frontage rule only were applied. Significant of the movement in this direction are the provisions of the proposed amendments to the charter of St. Louis, now pending. The proposed change makes one-fourth the total cost of paving assessable according to the frontage of abutting property, and the remaining three-fourths is to be assessed by the area rule upon a district extending laterally to a line "as near midway between the street to be improved and the next parallel or converging street on each side of the street to be improved as the lot lines * * * will permit."

Though many cities assess for the renewal of pavements by the same method they use for the original work, there is a significance in the fact that of the cities given as assessing for the first paving, about 40% charge the city with all, or a greater percentage of the cost of repaving. Nor can it be denied that there is a basis of sound reasoning in the stand taken by the Pennsylvania courts, as given at some length in Section 26 of the Appendix, denying the right to assess the cost of renewal, though the resulting difficulties encountered by some of the Pennsylvania cities in repaving, and the policies of the other States both indicate that the State carries the argument too far. Nevertheless, when suburban property has been made more definitely urban by the construction of a pavement along its front, when lines of travel and traffic have become concentrated and established, and when a city has reached an age of the life of a pavement, and has disposed of the mass of expenses crowding upon its sudden growth, there is much reason and justice in charging it for a renewal with

* Appendix, Sections 16 and 20.

double the percentage that it pays for the original pavement. Provisions permitting a majority of property owners to choose the kind of pavement to be relaid, and, in consequence, charging them as for an original work, or the laying of a better pavement than the first, and so charging all the excess cost upon the property*, furnish wholesome variations that might frequently be taken advantage of and relieve a city of a portion of its percentage. When repair amounts to a renewal is an interesting question. Buffalo decides that when one-third or more of the pavement must be replaced, it becomes a renewal.

Repairs are always a general expense to the city, except where maintenance clauses occur in the contract for the original work. The incorporation of such clauses is of recent origin and the range of judicial opinion upon their legality is covered by Section 27 of the Appendix. The diversity in the decisions there given is marked; but if an opinion may be hazarded now upon the probable outcome, it would be that maintenance clauses will be held valid where the contract makes this agreement a simple warranty of the quality of material and work, and where the term of years, during which repairs, if found necessary, must be made by the contractor, is not so long as to make it appear to be an attempt to put indirectly upon the property the cost of repairs. The trend of the more recent judicial decisions seems to be in this direction. A large number of cities include maintenance clauses in their paving contracts, and the custom is growing, a recent example being the clause in the new charter for Greater New York authorizing their incorporation.

For the mains and laterals of a water-works distributing system, although circumstances lead a majority of the cities to construct either partially or wholly from the collection of water rates, a large number generally follow the same method of apportioning the assessment upon private property that prevails in the case of pavements. The system of apportionment suitable for paving assessments seems very applicable also to such a distributing system. Still, the percentage allotted to private property might well be increased in the case now under consideration, because, unlike the streets, the water-distributing system is not subject to constant use by the general public over all its extent, but rather its utility is monopolized by those connecting with

* See Exhibit, Chapter vii, Section 6.

the pipes; and because the use of public water will be encouraged where a considerable expense is thus charged to property, for bringing the water within its reach, whether the opportunity is availed of or not. It is quite customary for assessing cities to charge property only to the extent that would cover the cost of a small size of pipe; and this by assessing its actual cost, or a fixed charge per front foot varying from 65 cents to $1 25. Occasionally there is an annual charge per front foot for a term of years, intended to amount to the same as a single total levy. The expense of house connection is generally paid by the house owner, and occasionally there is an additional fixed charge for connection to increase the city's revenue; but as the latter would tend to discourage the use of the water, its imposition is impolitic. The cost of hydrants, valves and other public appurtenances naturally falls upon the city.

Of the 3 196 water-works systems in this country, furnishing a full supply to 3 480 cities and towns, 1 489 are owned by private companies*, but their number is constantly decreasing under a general policy favoring municipal ownership. The cities owning and operating their water-works have generally paid for the supply system by issuing water bonds, the interest of which, as well as the principal as it becomes due, is paid by general taxation, or more frequently by so fixing the water rates charged consumers that the resulting revenue shall, in part or even wholly, provide for this expense, as well as for the ordinary cost of maintenance. The size of the rates varies greatly, the enormous range being much influenced by the varying customs of different cities, some paying all the water-works expenses from the income derived from water rates, others so meeting a smaller portion of these expenses, and others providing for only a light outlay from the direct contribution of consumers. Of the half-dozen cities whose rates are given, the charge for metered water varies from 4 to 30 cents per 1 000 galls., the average being about 10 cents, when the daily consumption is only about the amount stated.

Whether all the expenses occurring in the management, maintenance and extension of the water-works system should be met entirely from the revenue derived from water rates or rents may well be questioned. Undoubtedly this method is legal, but it is doubtful if it is entirely just. Of course if water were used by every property owner

* *Engineering News*, Vol. xxxvii, p. 265.

there would result a universal contribution, the same as when taxation meets a portion of such expenses, but such is not the case. All the general public profit from the water-works, the city as such secures direct benefit in fire protection and in other ways, and it is submitted as tending only to equal justice that the city itself should share in the expense, perhaps to the extent of providing for the sinking fund to meet the payment of its water bonds, or an equivalent contribution. The practice of a large number of cities in assessing upon adjoining property the cost of laying a small size of pipe is also praiseworthy as an aid to the distribution of the cost more entirely where advantage results. Such practice as that of charging vacant lots, adjacent to water mains, with an annual tax per front foot does partially compensate for escaping all other contribution. The real purpose for which water-works are inaugurated, and the justification for their existence, the sanitary welfare of the citizens and their better protection and comfort, will be defeated to a greater or less extent if the rates are high enough to discourage connection; and compulsory laws under such circumstances cause irritation and objection. A certain contribution from the general taxation and partial assessments for the extension of the distributing system not only lessen the water rates and promote justice, but tend to encourage the use of water by those so charged; for, otherwise, they will secure no direct return for the assessment.

In a majority of cases the city pays for main sewers, either wholly or all above the usual assessment for a branch sewer. A large number also assess this expense by the area method upon the property affected, either entirely or all exceeding the usual charge for a lateral, as before. Less commonly a percentage is assessed, and the city pays the balance, or the cost is divided between an area and a frontage charge, or other plans are followed in its distribution. Of the methods pursued in providing for the collecting system, consisting of the laterals or branch sewers, a plurality prefer to charge the cost upon abutting property according to the frontage rule; though nearly an equal number have an arbitrary rate per foot front varying from 30 cents to $2, the city to pay the balance ; and a considerable number assess the cost either upon the drainage district or upon a zone of a certain width on each side of the sewer, in the ratio that the area of the lot or land in question bears to the total assessed area, streets being

excluded. Of the remaining methods, some divide the expense between the city and private property by various processes, others charge it upon property by a combination of the frontage and area rules, and sometimes the city bears the whole cost.

The frequently occurring plan of assessing upon contiguous property the equivalent expense of a sewer of small size, where a large sewer is placed, is commendable. This method would obviously have no advantage where the total cost of both mains and branches are together distributed pro rata upon all the property benefited, nor any application where the city pays entirely for its sewer system; but where adjacent property is charged with a certain part or all the expense of the sewer, inequality would result if the method just indicated, or an equivalent specified fixed charge not depending on the size of pipe, is not applied. Necessarily the larger sewers are laid on the lower ground where, except manufactories and similar industries, the less valuable and productive property occurs. Here, also, are more generally found tenements and the habitations of laboring men who are less able to meet the burden, while the commercial districts, and especially the dwellings of the more prosperous, are in the higher portions of the city, where the sewers are naturally of smaller size. The latter classes of citizens make the greater use of sewers, and it would manifestly be unjust to fail not only to lay upon them an equal burden, but to charge them even a smaller amount than the average. The cost of appurtenances, like manholes, lampholes, catch-basins and flushing tanks is sometimes met by the city and sometimes included in the cost of the sewer and so distributed. The disposition of these expenses depends upon the provisions of law.* House connections with the sewer are made at the expense of the property. In addition a few cities impose a special charge for the privilege of connection for the purpose of increasing the sewerage fund of the city; but this is to be deprecated as tending to discourage the general use of the sewers, which has become a sanitary necessity in cities.

The question of the distribution of the cost of a sewer system is also a complicated one, whether considered in the light of practice or principle. All the city has an interest, both general and sanitary, in its sewers, and the property-owners have a direct interest as abutters as well as a particular, but more general, one in the larger mains of their

* See Exhibit, Chap. viii, Secs. 12 and 13.

district sewers. As far as the trunk sewers are concerned, their construction is of more general import to the city as a whole than to any individual users, and their cost might well be paid by general taxation. Whether or not the city's share in building sewers should always be devoted to these mains, because they have the least direct connection with property, may be uncertain, as custom or local usage may dictate the assumption of the cost of work on street intersections or in front of city lots, parks and other property, or other expenses, besides the occasional defaults that come upon the city, all of which would probably equal the proportion suggested. All the reasons already given for considering it equitable for the city to share in the expense of its water-works system apply equally to its sewer system; where there are no storm-water sewers, a separate system, for which the city usually pays, it is but just that the city should aid in the construction of the more usual combined system, which has to receive the storm water from the streets. It would be unfair to expect lots or lands, so distant that they may not be able for years to secure connection with the system as it develops, to contribute much toward paying for trunk sewers which will at best be of only indirect special advantage to them; and it is believed that the city assuming a share, to the extent of 20 or 30% of the cost of its sewer system, would furnish but a fair equivalent for its benefit, and make less burdensome the individual assessments which so frequently cause objection and retard the construction of these necessary improvements.

Of the methods followed, perhaps the most adequate plan of dealing with the portion of the expense of sewers that is to be assessed is that common one of considering together all the sewers of each sewer district and distributing the cost over the district in proportion to the advantage received. In many cities this allotment is attempted by the frontage rule, but deep lots generally have a larger share in the use of sewers than have shallow ones of the same frontage. The amount of storm water to be removed from lots is far from having a definite relation to frontage, and other irregularities result. Other cities apportion this assessment by the area rule, but of equal areas that which has the greater frontage enjoys conditions favoring a larger number of buildings or other improvements which imply a greater interest in the sewer system, and therefore should furnish a correspondingly larger contribution; and as systems are often built a portion at a time, lands

remote from the constructed portions should not be required to pay equally with lots that are enabled to make use of them at once.

In consequence of the inequitable features inhering in both systems, in numerous instances it has become an improved method to combine the two processes and assess 40%, more or less, by frontage and the balance by the area rule, or to apply some equivalent procedure that will effect a similar combination of methods. This system of apportionment is growing in favor. It corrects the more serious errors of either method used alone. It is not complex in application, and in principle it is as definite and as easily understood by the people affected as either single process. Probably no more adequate plan for sewer assessments has been extensively used than, after the city has contributed its due portion, assessing by frontage an amount equal to the cost of a smaller size of pipe upon abutting property, as previously mentioned, or an equivalent amount, and distributing the remainder in proportion to area.

In some Massachusetts cities the plan has recently been applied of partly paying the cost of the sewer system and its maintenance by a sewer rental corresponding in its principle to the water rates of water-works systems. The private contribution to sewerage construction should correspond very closely to the use made of them; and to effect this, Brockton and other Massachusetts towns* have adopted the plan of such an annual charge depending upon the amount of water used, claiming that the quantity of sewage to be disposed of can be approximately estimated by reference to the water rate. If this plan does not tend to discourage the use of sewers, if it does not too much complicate the system of assessment, and proves otherwise practicable, it may furnish a valuable addition to the methods of apportionment. Its practical operation will be watched with interest by those making a study of special assessments.

Of other classes of assessable works that of street sprinkling is growing in importance, and is becoming quite common. About half of the cities given make sprinkling a public concern, and a majority of these assess the cost upon abutting property according to its linear frontage. In Sections 22, 23 and 24 of Chapter VII of the Exhibit are given details of the method of providing for such assessments, which must have charter sanction to be legal. The same legislative counte-

* See *Journal* of the Association of Engineering Societies, Vol. xviii, pp. 1-63.

nance would seem fully as necessary to effect the assessment of municipal duties which have been generally considered a city charge; but with such provision, street cleaning, for example, may be assessed.

To guard against wanton extravagances, such as are mentioned in the Appendix, Sections 17 and 28, as well as to protect private interest against lesser encroachments or undue burdens, it is the condition of a considerable proportion of the cities to be restricted in the amount that can be assessed for each improvement. This limit is sometimes given as a certain amount per foot of frontage or of area, but is more frequently a fixed percentage of its tax valuation. For the cities here reviewed this ratio varies from one-fifth to unity. Occasionally there is a variation, such as a limit of 25% if property does not petition for the improvement, which becomes 100% where petition is made. There may be much question about the proper amount of this percentage. Certainly it should not be so small as to prevent necessary works, nor so large as to offer no effective check in preventing undue burdens. Its application may be in complete abeyance; but if a contingency arises when its influence is required, immediate advertence to its agency furnishes a ready remedy against excessive charges.

The principle of special assessments for public improvements is too firmly established and too well proved to be questioned. Although the attempt has here been made to indicate the injustice of certain extremes of practice that are in vogue, and to suggest methods that should secure a more exact equity, yet the author realizes the undesirability and impossibility of an attempt to consider any rule of apportionment fixed and rigid. The differing conditions, requirements and circumstances of municipalities make a system that may be most impartial for one city unfair for another; and here the elasticity of the principle exhibits its most salutary quality. While so framed as to preserve the essentials of justness, its details may readily be adjusted to harmonize with local conditions.

But this elasticity, so efficacious in its general scope, cannot be invoked to unsettle established practice without defeating the justice which it should serve. Uncertainty of what to expect, or constant liability to change, is frequently worse than the opposite extreme. Where a city has for years made its improvements by a certain method it would obviously be unfair to change completely; as where the cost of paving streets has been a city expense and a portion of them have

been so improved, it would be inequitable to property owners on streets about to need pavements to change this policy to one requiring the abutters to pay thenceforth for such work by assessment, because they have already contributed their share by general taxation to the improvement of the streets that have been paved, and should therefore obtain an equivalent return for their own.

Cities having, then, a system established by laws and usage cannot radically change, even if the proposed methods are better. The approach to superior procedure must be by successive approximations made when conditions favor revision, and in a manner that will most equably distribute the charge, as indicated in the light of past contributions as well as of future assessments. A new city, just adopting a system, can escape much of this labor toward more perfect methods by securing, in the beginning, a plan suited to its circumstances; but even here it is recognized that any system may be somewhat tentative, as it may not develop the efficiency and adequacy expected. Further, the extension of the principle to improvements theretofore not covered by special assessments involves experimental methods that can be perfected only by the test of experience. And so in any case occasional, but not injudicious, revisions must be made, the effect and influence of the local law, the experience of other cities and the legal interpretation of the laws, all guiding toward superior provisions. In this way practice and theory may more close unite, and, by impartially distributing the charge wherever the benefits are received, secure that equal justice, the necessity for which forms the plea of the opening paragraph of the paper.

APPENDIX.—THE LAW OF SPECIAL ASSESSMENTS.

Introduction.

1. Nature and Limitations.—In so far as a special assessment is a contribution enforced by the authority of the state to raise revenue for public purposes, it partakes of the nature of a tax. Because it is levied upon property in proportion to the benefits received, there result some principles differing from those of general taxation. Constituting a branch of the power of taxation, special assessments must conform to the limitations imposed upon the taxing power, to the extent that (1) they must be for the public welfare, (2) they must be imposed only for public purposes, (3) they must be levied by due

process of law, and they must conform to requirements of the federal Constitution, (4) forbidding the taking of property without just compensation, (5) not permitting the impairment of contracts, and (6) guaranteeing the equal privilege in a state to citizens of other states. They differ from taxes in so far that (7) the power to levy them may be delegated by the Legislature to municipalities, and (8) they are not to be imposed upon all the citizens in proportion to the property valuation of each, even where there is a constitutional provision requiring equality and uniformity in taxation. Other restrictions may be imposed by the state Constitution; but unless thus expressly prohibited, the power of the state Legislature is supreme and its discretion is conclusive.

2. *Limitations Explained.*—The first requirement just mentioned (they must be for the general welfare) follows one of the fundamental principles of the purpose of government as stated in the federal Constitution, and is a question for the Legislature only to determine. The second necessity (a public purpose) is also a legislative question, but one in which the courts may act if its requirements are disregarded by the Legislature. The third essential is administered in a way to guard private rights especially, and is covered by the following subdivision: "Procedure in their levy and collection." The fourth requisite is secured by the fact that the fundamental principle of such assessments considers them as levied to pay for the special benefits which accrue over and above the benefits to the general public. The fifth and sixth needs affect mainly the interest of bondholders, as discussed under the title "The Validity of Improvement Bonds." The seventh characteristic is constantly and universally exercised by state Legislatures in their paramount authority; and the eighth principle is rejected by only Tennessee and Arkansas[1].

Procedure in Their Levy and Collection.

3. *Flexibility of Method.*—The adaptability and justness of the principle involved is indicated by the flexibility in the method of procedure that the system permits. Not only is the special assessment laid in proportion to the benefit received, but the latitude of methods pursued in its levy and collection permits of a ready adaptation to the special conditions and needs of each case.

4. *Legislative Authority.*—Although the Legislature is the supreme power, it delegates its authority more or less completely and very specifically to the municipality by a charter or by general laws under which the city acts. In every case these specific legal provisions govern the mode of operation, and are to be strictly followed in each step of the procedure.

[1]See p. 355.

5. Initiative Proceedings.—Sometimes the city council or an executive board, such as a board of public works, has authority to proceed at once; but more frequently there is necessary some antecedent action, such as a petition of a portion or a majority of the property-owners affected[1]; or a favorable vote; or a remonstrance from a certain proportion of the interests affected may postpone action for a definite time, or otherwise affect the proceeding. To facilitate such action by the interests affected, notice of the proposed improvement is generally given before making the assessment, and usually opportunity for a hearing for and against the proposition is furnished by the body having jurisdiction, either before or after the apportionment is made.

6. Distributing the Assessment.—Assessing the cost upon the property affected is the work of assessors or commissioners. Generally the assessors are especially appointed for the purpose by a court or some other specified body, but frequently certain officials serve. It is usual for the extent of the assessment district to be prescribed by the municipal body mentioned in Section 5, but occasionally the Legislature prescribes it; otherwise the assessors generally fix its limits. Much the same course of action obtains in fixing the rule by which the assessment is apportioned; but whether it is by area, by the front foot, or otherwise, the method is followed which is supposed to distribute the expense most nearly in proportion to the benefits received. Sometimes the amount that can be assessed is limited by law, either by a provision that the assessment shall not exceed a certain percentage of the assessed valuation, or the proportion to be charged upon the property may be fixed and the city pay the balance, or the maximum charge may be specified per foot or otherwise, or limitations may be effected by other restrictive provisions.

7. Collecting the Assessment.—The assessment becomes a definite charge upon property when the procedure of Section 6 is authenticated and confirmed by the body which took the initiative proceedings or the one which appointed the assessors, and it is usually declared by statute to become then a lien upon the property. The special assessment is generally collected by the city officials, either as ordinary taxes are collected or by a prescribed special process; but in some cities the assessment bills are given the contractor in payment for his work, and are collected by him. If necessary, the collection of the assessment is enforced, when it becomes delinquent, by specific legislation permitting a sale of the lands, or by some of the processes adapted from the method of collecting general taxes.

8. Remedies of the Tax-Payer.—While the ordinary legal remedies are always open to the tax-payer for testing the legality and justice of an assessment, and furnishing his ultimate remedy, yet the procedure just outlined contains his usual safeguards in giving him one or several

[1]Exhibit, Chapter vii, Section 6.

of the following privileges; a voice and a power in the initiative, a hearing before the administrative body, a review by the assessing board, or an appeal to some court or to the confirming board. Where "these laws provide for a mode of confirming or contesting the charge * * * with such notice to the person, or such proceeding in regard to the property as is appropriate to the nature of the case, the judgment in such proceedings cannot be said to deprive the owner of his property 'without due process of law'";[1] as such provisions specifying details of procedure are within the unquestionable and unquestioned authority of the Legislature, and so, when formulated, are a part of the law of the land.

9. *Prescribed Procedure Must Be Strictly Followed.*—Whatever be the precise character and nature of each of the successive steps prescribed, in any case, for making a special assessment, the fact remains that usually such statement of procedure, in the charter or general laws, is very complete and explicit.[2] In any case it is necessary that the requirements so specified be exactly followed to secure legality in the assessment. Unimportant details would not constitute decisive irregularities; but any departure from the prescribed procedure at all material or important is always held to invalidate.

Interpretation and Judicial Decisions.

10. *Power of Legislature Paramount.*—In matters of taxation the authority of the Legislature, paramount within its proper limitations, permits such a delegation of authority to the municipality as it deems best. Such delegated power may be extensive or meagre, generous or restricted, in the quality of its provisions, adequate to the city's needs, or most circumscribed, efficient and salutary, or unwieldy and insufficient. Not only this, but such authority may be subsequently enlarged or restricted, confirmed or recalled, modified or resumed by the Legislature whenever it deems it wise and in whatever way, subject to the restrictions given in Section 1. Indeed many customary provisions, *e. g.*, a favorable vote of the people before proceeding in certain cases, are discretionary and may be omitted if the legislative power sees fit. Where they are not strictly of exclusively local concern the Legislature may even coerce an unwilling municipality into making needed public improvements, *e. g.*, requiring a city to lay out a street without its consent or vote, and obliging it to issue bonds in payments,[3] in short, exercising "directly within the locality any or all of the powers usually committed to a municipality."[4] Where the state has special, restrictive, constitutional provisions, a local improvement cannot be so ordered and assessed.[5]

[1] 96 U. S., 97, 105.
[2] Notice details of Exhibit.
[3] 46 N. Y., 401.
[4] 81 U. S., 540, 545.
[5] 51 Cal., 15.

11. The Grant of Power Must Be Clear and Strictly Followed.—Confining the consideration more closely to special assessments, "it may be considered a point fully settled * * * that the Legislature has the constitutional power to confer on municipal corporations the power of assessing the cost of local improvements upon the property benefited. * * * It becomes a mere question of expediency of which the Legislature are the competent and exclusive judges, and not of right."[1] There being, then, no question of the authority of the state to confer, either with or without restriction or limitation[2] except constitutional, there comes the question of the grant of this power. It is essential that authority to levy special assessments must be clearly and plainly given by the state, or implied by being absolutely necessary to the exercise of a power expressly granted, as otherwise the city will have no such power; no equivocal or doubtful implication will suffice. Similarly the extent of the power is limited to that clearly given, and the mode of exercising it, as prescribed, must be carefully followed.[3] The question is, then, has the state delegated the power to make special assessments to the city, and with what fulness and what restrictions ?

12. Legislature Must Not Exceed its Authority.—Although it has been frequently held that the legislative judgment shall stand almost to extremes, the courts have lately shown a disposition to scrutinize more carefully the powers granted and the effect of their exercise, holding them more closely to the limitations before given.[4] As where the Legislature declares that the total cost of improvement, without regard to whether such cost exceeds the benefit conferred or not, can be assessed upon property, the courts are becoming inclined to consider such provisions arbitrary and unjust, as far as the excess above benefits is concerned, considering that such excess must be borne by general taxation;[5] and several courts have recently held that, where the provisions of the law were of such a nature as to make it legally impossible to apportion the burden with substantial equality and justice, it is not a lawful exercise of legislative power.[6]

13. Power of the Municipality is Restricted.—The construction of the powers as granted by the Legislature[7] furnishes the measure of power that may be exercised by the municipality. Therefore, while the state's power is limited only by the restrictions given at the beginning, that of the city extends only to the powers plainly conferred upon it by charter or statute. Neither can the municipality confer power upon other bodies which were intended for it to exercise.[8] Nor can charter requirements be varied by ordinances, as, when a city

[1] 65 Pa., 146, 150.
[2] 7 Bush (Ky.), 667.
[3] 8 Wash., 84.
[4] See Sections 1 and 2.
[5] See Section 16.
[6] 34 Ill., 203.
[7] See Section 11.
[8] 105 Cal., 244.

charter makes the determination of the size of a city sewer a duty of the city council, the exercise of this function by the city engineer invalidates the assessment.[1] Nor can a city ratify proceedings which were illegal in the first place, so as to make them valid; the power of legalizing by curative legislation exists only in the state Legislature.[2] But for a city that began work on a sewer on a defective ordinance which was replaced by another ordinance curing the defect while construction was progressing, it was held that the resulting tax bill was valid.[3] A city may, as a rule, alter or change its system of sewerage if for the public good;[4] but where an act of the Legislature contemplates one main with its laterals for a district, the commissioners have no right to substitute a system providing for two mains instead.[5] Authority to make local improvements by special assessment does not permit assessing the cost of street sprinkling;[6] but it may be so assessed when statute permits.[7] A city ordinance providing for the assessment upon property owners of the expense of street sprinkling and sweeping is held valid under the police power.[8]

14 *Incidental Powers.*—A given power to pave includes power to do all that is necessary, fitting or customary for paving; hence, trimming and guttering have been held to be incident to macadamizing;[9] similarly, grading, curbing, etc., are incidental to paving, and so may be included in the assessment.[10] Further, charter authority to a city to repair and keep in order its streets is sufficient to empower it to construct drains and sewers without more special authority; and when constructed, the municipality will incidentally possess power to pass ordinances regulating their use.[11] A city authorized to construct sewers cannot be restrained from removing a street railway from the street, if that is necessary.[12] A city that permitted a gas company (under contract based on a valid consideration) to lay its pipes in the streets does not thereby lose its power to lower the grade of the streets subsequently and to remove, if necessary, the exposed and obstructive gas pipe as nuisances. The municipality and not a court must judge the necessity of exercising the power to grade and improve its streets, and a city cannot alienate such power when vested in it by the Legislature.[13]

15. *Improvement Must be of Special Local Benefit.*—Although decisions are numerous, logical and spread over most of the time that local assessments have obtained, holding to the fundamental doctrine that to pay for local improvements entirely from the general fund would

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[1] 52 Mo., 133.
[2] 36 Cal., 239.
[3] 52 Mo., 348.
[4] 38 La. Ann., 308.
[5] 37 N. J. L., 51.
[6] 149 Ill., 310.
[7] 41 N. E. Rep. (Ind.), 1 045.
[8] 130 Ind., 382.
[9] 22 Iowa, 246.
[10] 2 Mich., 560.
[11] 28 Conn., 363.
[12] 48 Md., 168.
[13] 88 Va., 810.

be inequitable,[1] yet it must be remembered that the converse holds true, such assessments being generally held unlawful when there is no special benefit derived by the property in question above the general benefit received by the community at large. To make the special assessment valid, its purpose and effect must be to benefit the property in the vicinity of the improvement, and not the public generally. Of the cases upholding this well-established principle, one held it beyond the power of the Legislature to require the owners of farm lands lying within one mile of a certain public highway to pay for its improvement by special assessments, because it was a general public benefit.[2] Again, a general power to grade and pave does not permit a city to grade and pave a public street for the general benefit, and assess the total cost upon the abutting property.[3] "Local assessments can only be constitutional when imposed to pay for local improvements clearly conferring special benefits on the properties assessed, and to the extent of those benefits. They cannot be so imposed when the improvement is either expressed or appears to be for general public benefit."[4] Again, "an ordinance providing for a street improvement, the estimated cost of which exceeded the value of the property to be charged therewith, and which did not enhance the value of the said property to anything like the cost of said improvement, is an unreasonable exercise of the taxing power."[5] Where it clearly appears that the property is in no way benefited by the alleged improvement, the assessment is unconstitutional; its "enforcement * * * would be taking property without due process of law."[6]

16. Assessment in Proportion to Benefits.—The Legislature has a wide discretion in providing the manner of determining benefits, but whatever method is fixed upon must conform to the principle of payment according to benefits received.[7] "Burdens in excess of benefits * * * must be borne by general taxation."[8] While this principle of payment according to benefits is fundamental, it is not necessary that it be true for every individual case. If it holds broadly true for the special assessment as a whole, the fact that there may be isolated exceptions will not invalidate the assessment. Occasional exceptions, perhaps working hardship, cannot be always provided against; and its general justice upholds it.[9] The same is true where an assessment district may not include just the property especially benefited; of course that must be the intention and the general rule, but individual exceptions will not invalidate.[10] But the city cannot purposely, as by contract, exempt property that would be

[1] 10 La. Ann., 57.
[2] 69 Pa., 352.
[3] 48 Md., 198.
[4] 65 Pa., 146, 157.
[5] 33 S. W. Rep. (Mo.), 182.
[6] 25 Ore., 229, 240.
[7] Exhibit, Chapter VII, Sections 2 and 6.
[8] 36 N. J. L., 291.
[9] 12 Colo., 593.
[10] 35 Mich., 155.

subject from the payment of its proper proportion.[1] A lot, though below the grade of a sewer, has to pay its portion of the assessment, as it will be benefited whenever it shall be filled.[2]

17. New Jersey Insolvent Cities.—The principle that the assessment upon property must not exceed its exceptional benefits is strongly upheld in the famous "Agens" case,[3] which resulted in involving several New Jersey cities in insolvency. In these cities, notably in Elizabeth, miles of pavement were laid in the suburbs and in outlying districts that were not built up, and the cost was assessed upon abutting property, city bonds having meanwhile been issued for immediate payment of the improvements. Lawsuits and delays over the collection of the assessment resulted, and property values declined to such an extent that often it was worth only a fraction of the amount levied. Then came the "Agens" decision just noted, preventing the cities from even partially reimbursing themselves for the improvement bonds issued in anticipation of the collection of the special assessments now decreed invalid. The New Jersey Legislature passed laws for relaying these assessments in a constitutional manner, but by this time the value of the property involved had decreased to so much greater an extent that the remedy was ineffectual. The burden was too great to be borne, city officials resigned to prevent suits against the municipalities involved, and for months the collection of taxes, and the usual city acts and official duties dependent upon taxation, practically ceased. Finally the State passed the Incumbered Cities Relief Acts, which enabled them, after years of the greatest disturbance, to compromise their debts and resume their proper functions.

18. Equality and Uniformity Interpreted.—Though special assessments need not be equal and uniform in the sense that general taxes are required to be,[4] yet so far as interpreted that phrase has been generally held to mean that the special assessment must be apportioned by some uniform principle securing an equality of burden as measured by the standard of benefits.[5] Thus, while the city charter of Covington, Ky., required in the initiative a majority petition for all streets, except its main thoroughfare, it was held that the taxation requirement of uniformity applied to special assessments to the extent that a majority petition must be secured for that thoroughfare also, although the city charter expressly stated that it could be paved, and the cost assessed without any petition therefor, but by unanimous vote of the council.[6] So, too, while decisions favor first the constitutionality, and then the unconstitutionality of the method requiring a property owner to pay the exact and whole expense of the particular part of the improvement in front of his own

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[1] 69 Tex., 180.
[2] 7 Cush. (Mass.), 277.
[3] 37 N. J. L., 415.
[4] 94 Ky., 396.
[5] 51 Cal., 15.
[6] 8 Bush. (Ky.), 493.

property, the safer opinion seems to be that such a procedure lacks the uniformity as well as the apportionment required.[1]

19. Principle of Apportionment.—The apportionment of the assessment upon the property affected may be left to the assessors, but it is more generally placed by some definite method formulated either by the Legislature or by the city council, the underlying principle still being assessment in proportion to benefits. If left to the assessors it is easy to apply, in any case, the mode that seems most effectively to conform to the requirement just mentioned. But if by some formulated method, it is equally true that the principle of benefits should control the determination of the method, so that the formulated rule will lead to practically the same result. "The only safe and practicable course, and the one which will do equal justice to all parties, is to consider what will be the influence of the proposed improvement on the market value of the property; what the property is now fairly worth in the market, and what will be its value when the improvement is made. * * * There can be no justification for any proceeding which charges the land with an assessment greater than the benefits. It is a plain case of appropriating private property to public uses without compensation."[2] Where the law provides a specific mode of apportionment it must be carefully followed; as, where the statute provides for assessment on "lands fronting on the street improved in proportion to the benefits upon the property," an assessment arbitrarily proportioned to linear feet of frontage is invalid.[3] The report of the assessors must show distinctly that the assessment is in proportion to benefits; it could not be permitted that a jurisdictional document of this nature should speak in ambiguous terms.[4] A report of the majority is the report of the assessors.[5]

20. Details of Apportionment.—Of the formulated methods of apportioning the assessment, mentioned in the last preceding section, those by amount of area and by extent of linear frontage are the most used. These methods, when prescribed, have been upheld by the courts except when lots were of such various size, depth or situation as to defeat practically the benefit requirement in the frontage rule; or when lots were so different in position or condition as to work practically the same injustice under the area rule. Under the latter method a special assessment levied according to area, but with the corner lots required to pay 25% additional, was declared unconstitutional.[6] On the other hand, when lands remote and near were assessed equally it was held so arbitrary and so opposed to the benefit principle as to make it unlawful;[7] but a similar assessment was held constitutional under the police power.[8] In the case of the frontage rule,

[1] 145 Ill., 313.
[2] Cooley on Taxation, p. 459.
[3] 9 Wash., 466.
[4] 30 Mich., 24.
[5] 63 Barb. (N. Y.), 572.
[6] 12 Bush (Ky.), 570.
[7] 35 Mich., 162.
[8] 10 Colo., 112.

the same underlying principle (that of benefit, of which this method is, or should be, but an index) is again the test, and where followed the assessment is upheld;[1] but cases are not rare where courts have declared them illegal simply because they violate that principle.[2] Lots separated from the improved street by a railroad running parallel to it cannot be taken as fronting upon the street; and an assessment upon them by the frontage rule will not hold.[3] Corner lots, having thus a double frontage, may be properly assessed the total amount determined by their linear extent on both streets, where both streets are improved;[4] though the usual way is to abate a certain percentage of the assessment on one front,[5] and there are cases where, when a corner lot has its longer dimension abutting on the improved street and its shorter dimension on another, it was held that the lot should be deemed as fronting on the improvement only to the extent of its shorter dimension;[6] but the usual rule in such cases is that the frontage of a corner lot is "its frontage upon the improvement," although the condition of the lot and its improvements make its proper front (as usually considered in other connections) on the cross street.[7] Further, charging benefits by frontage, and so assessing, could apply only to cities and towns where the density of population and the small size of lots make this a reasonably certain mode of arriving at the true result; to apply it to the country and farm lands would lead to inequality and injustice.[8] It is customary to provide that street railways shall pay for that part of the improvement covered by their tracks;[9] and where such paving is made the duty of the street railway, its cost cannot be included in the assessment upon private property.[10]

21.—*Principles Affecting the Validity of the Levy.*—The confirmation of the assessment[11] by the municipal or judicial body having such authority is the definite action which transforms the preliminary process into an accomplished fact, definite, conclusive and binding. If a city council refuses to act, it may be compelled to do so by mandamus.[12] A supreme essential in the preliminary procedure is that notice to those to be assessed must be provided for at some stage of the proceeding. "The law must require notice to them and give them the right to a hearing and an opportunity to be heard. * * * The Legislature may prescribe the kind of notice and the mode in which it shall be given, but it cannot dispense with all notice."[13] Of course, these preliminary steps have their rules of procedure, specified gener-

[1] 56 N. J. L., 119.
[2] 96 Ga., 381.
[3] 35 Pa. St., 75.
[4] 32 Iowa, 271.
[5] 140 Ill., 402.
[6] 50 Ohio, 471.
[7] 131 Mo., 19.
[8] 69 Pa., 352.
[9] 97 Cal., 305.
[10] 144 Ill., 446.
[11] See Sections 6 and 7.
[12] 42 Ark., 152.
[13] 74 N. Y., 183, 188.

ally by charter, that must be faithfully observed,[1] and a decision or certificate of the proper authorities that such has been done is *prima facie* evidence of compliance, but when not made final and conclusive by statute,[2] it may be disproved;[3] the lack of such substantial compliance with the specified procedure makes the whole proceeding void. "The power of taxation, especially for local improvements, is the highest attribute of sovereignty. * * * Such statutes must be construed with the greatest strictness."[4] But in the absence of fraud or mistake the administrative acts and discretionary decisions of this board are authoritative and final; and "the decision of the board * * * is conclusive."[5] It is this confirmation and levy that definitely brings the property owner into the legal relation, the city previously acting and contracting for the improvement, although private property is to pay for it. Such an assessment is not subject to counterclaim or set-off.[6] Although the property owners are not parties they may defend against paying the assessment if there has not been a substantial performance of the contract; as, where only a part of the improvement has been made, abutting property owners cannot be compelled to pay, even when an allowance is made for the work not done.[7] There may also be a successful defence if there is no possible benefit to the property; as where the owner of a corner lot had applied to the city council for the use of water and had paid for the pipe laid in consequence along one front of his property, he was held not liable to assessment for pipe afterward laid along the other front without his petition.[8] If a contractor is violating his contract by doing the paving in an imperfect manner, a landowner (if the city authorities unreasonably refuse to take action) may secure an injunction restraining the council from paying for such work, where the landowner is liable to assessment for the improvement;[9] or such landowner may maintain suit to enjoin when the work is being done under an illegal contract;[10] or he may attack the assessment if it is void.[11] On the other hand, defective work will not offer a valid defense, when the assessment becomes due, against paying it; the proper city officials decide this question. The taxpayer having failed to avail himself of his opportunity to have such charge reviewed in the regular course provided by law, he cannot now question the approval of the work by the superintendent, which he had acquiesced in.[12] Nor will alleged irregularities and failure to comply with minor statutory requirements invalidate, unless facts are given showing such irregularities.[13] Neither will the fact that a property owner, as-

[1] Exhibit, Chapter vii, Sections 9, 11 and 12.
[2] 62 N. Y., 457.
[3] 4 Hill (N. Y.), 76.
[4] 59 Ark., 344, 362.
[5] 33 Minn., 295, 304.
[6] 39 Cal., 389.
[7] 14 Bush (Ky.), 24.
[8] 86 Pa. St , 489.
[9] 48 N. J. Eq., 275.
[10] 137 Pa. St., 548.
[11] 43 N. E. Rep. (N. Y.), 632.
[12] 29 Cal., 75.
[13] 81 Wis., 326.

sessed for the construction of a public sewer, had previously constructed a private sewer (sufficient for the needs of his property and with the assent of the city) relieve him from such assessment, even when a municipal building had connected with the private sewer.[1] As a rule, a municipal corporation cannot exercise its powers beyond its own limits;[2] but when it is necessary to extend a sewer beyond such limits in order to obtain an outlet, a special assessment to include this expense will stand.[3]

22. *Time of Levying and Methods of Collecting.*—In most cities the assessment is levied after the cost of the improvement is known, the city meanwhile advancing funds (if necessary) for the prosecution of the work, and securing reimbursement upon the collection of the assessment. Where there is no legal difficulty preventing it, this is the better way, as it avoids complications which have troubled many cities, resulting in their abandonment of the system of making the assessment upon the basis of estimated cost. Such estimated assessment was generally found to be either too great or too small, necessitating either the return of an excess to the property owners or a reassessment to supply the deficiency. While such anticipatory assessment, rebate or reassessment has each been judicially upheld, the consequent difficulties, complications and hardships have caused its abandonment wherever possible. It is quite customary to provide that the contractor shall depend solely upon the proceeds of the assessment for his compensation; and this holds,[4] unless the city makes itself liable by reason of default or negligence in the proceedings.[5] Many cities, instead of anticipating the collection by the issue of bonds or otherwise, pay the contractor by turning over to him the special assessment bills. The contractor collects these bills, if necessary enforcing their payment, in his own favor, by the prescribed legal procedure.[6]

23. *Enforcement of the Collection.*—It is customary to make a special assessment a lien upon the property assessed, to be enforced by sale or other specified means if necessary. But such assessments are not liens unless they are plainly made so by the charter, or unless the city is unmistakably authorized by the Legislature to declare them liens. But lands may be sold for delinquent assessment where there is plain authority so to collect.[7] Assessments are also frequently declared to be a personal charge against the land-owner, and have been often enforced as such.[8] Yet it is difficult to reconcile this proceeding with the principle of benefits underlying the whole system of special assessments; and there are decisions sustaining this objection.[9]

[1] 168 Pa., 105.
[2] 154 Ill., 23.
[3] 138 Ill., 295.
[4] 16 Wis., 271.
[5] 1 Met. (Ky.), 339.
[6] 31 Cal., 240.
[7] 42 Neb., 186.
[8] 79 Iowa, 645.
[9] 50 Mo., 525.

Whatever mode of enforcing the collection is specified, it is to be faithfully followed, even to the exclusion of others; yet, where there is authority to assess, some adequate remedy cannot be denied. Where the mode of collection is not specified, the assessment may be enforced by due course of judicial proceedings, but not by distress and sale of the property unless that is permitted by express grant or is necessarily implied or absolutely essential to the declared purposes.[1] If money is paid for an assessment, void on the face of the record for want of jurisdiction, it may be recovered in an action at law; but for an assessment otherwise illegal it cannot be recovered until the assessment is set aside by judgment of court, and such decree in one case will not vacate other assessments for the same improvement, but judgment must be secured for each.[2]

24. *Classes of Property Exempt.*—Federal, state or municipal property is not subject to special assessment without definite authority to so assess. For example, school property has been held not liable to assessment for a street improvement,[3] but the city may be held for the amount;[4] nor is a public square subject to special assessment without plain statute authority;[5] nor, without such provision, are streets crossing the improved street subject to assessment as abutting property.[6] Such charges upon the property of religious societies (where they are exempted by the state from taxation) have usually been held valid,[7] the reasoning being that special assessments are not taxes within the meaning of such exemption laws; though in one case the contrary rule was upheld,[8] but the state has since (1891) reversed its decision.[9] Further, a provision in the charter of a corporation exempting its property "from all taxation by state or local laws for any purpose whatsoever," does not exempt it from local assessments.[10] Railroads, having a quasi-public character, involve the question with more uncertainty. In one case, where the federal government had important interests and definite connection with the railroad, it was decided there was no power to tax.[11] In another, where the direct benefits to the railroad (from paving) were uncertain, it was held that the roadbed was not subject to the special assessment.[12] Yet the better principle and the weight of judicial opinion holds that such property is liable for its proportion of the cost of a public improvement, its quasi-public character securing for it no exemption.[13] The fact that the property affected is a homestead does not exempt it from assessment.[14]

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[1] 25 Iowa, 163.
[2] 130 N. Y., 401.
[3] 48 Ohio St., 83.
[4] 35 S. W. Rep. (Ky.), 625.
[5] 115 Mo., 557.
[6] 150 Ill., 530.
[7] 8 Bush (Ky.), 508.
[8] 76 Ga., 181.
[9] 86 Ga., 730.
[10] 92 Ky., 89.
[11] 18 Wall (U. S.), 5.
[12] 138 Pa., 375.
[13] 25 Atl. Rep. (Pa.), 610.
[14] 97 Cal., 305.

25. Reassessments Valid.—The power to impose special assessments is a continuing one, unless otherwise specified. It is not exhausted, in relation to any certain piece of property, when one assessment has been made upon it. As where a sewer proved to be a nuisance as at first made, necessitating its continuation to a river, this situation was held to justify a second assessment upon the same property.[1] There may also be a reassessment upon the same property if the first has proved insufficient, even when there is a final decree of the court forbidding the collection of the original assessment.[2] A void assessment does not preclude a subsequent valid one.[3] But where there was a provision in the state constitution providing that no law retrospective in its operation should be passed, an act of the legislature authorizing a reassessment was held void under this provision.[4]

26. Reassessment for Renewals.—When the subject of reassessment for the renewal of a public improvement is considered, there is found less unanimity in the decisions. The prevailing opinion remains favorable to assess property again to pay for a renewal, either without restriction, as at first,[5] or under restrictions, such as that of the New York City charter of 1873, providing that repaving can be assessed only when the improvement has been petitioned for by a majority of the property owners.[6] The only state definitely holding views adverse to such reassessment is Pennsylvania, whose policy had its inception about the year 1870. In the judicial opinion then delivered the question raised was the legality of assessing the cost of repaving Broad Street, Philadelphia, with Nicholson pavement when the expense of paving it with cobble-stone had been previously assessed upon the same property. The decision was opposed to the legality of the proceeding, on the ground that "when a street is opened and paved, thus assimilated with the rest of the city and made a part of it, all the particular and especial benefits to the locality derived from such improvements have been received and enjoyed".[7] The principle thus established has been frequently reaffirmed by the Pennsylvania courts, and this remains the policy of the state, even to the extent of not permitting the assessment of cost of paving with asphalt when the same street had been previously macadamized at no expense to the property now levied upon.[8] The latest decision holds the principle applicable to reassessment for sewer construction as well. The following are extracts from this recent decree: "A sewer once constructed gives to the property owner every benefit and advantage that a sewer gives him over the general public. The benefits thereafter derived, either from repairing or reconstructing the same, are are only such as he enjoys in common with the public. * * *

1 44 N. J. L., 347.
2 34 N. J. L., 236.
3 79 Md., 469.
4 52 Mo., 133.
5 7 Bush (Ky.), 667.
6 77 N. Y., 523.
7 65 Pa., 146, 156.
8 151 Pa., 172.

There can (therefore) be no doubt that after a public sewer is once constructed, it must be maintained and repaired at the expense of the public. The question we are discussing, as applicable to paved streets, has been thoroughly settled by our Supreme Court, who have repeatedly held that the payment of the costs of the original paving out of the city funds was immaterial, and did not change the principle that a street once paved could not be repaved at the expense of the abutting property holders."[1]

27. *Repairs Paid for by City; Maintenance Clauses.*—Concerning the maintenance and repair of public improvements, decisions seem unanimously to uphold such work at the expense of the municipality. When an improvement is once made, the city must keep it in repair.[2] "Repairing streets is as much a part of the ordinary duties of the municipality—for the general good—as cleaning, watching and lighting. It would lead to monstrous inequality should such general expenses be provided for by local assessments."[3] Such being the rule, there arises the important question of the validity of maintenance clauses of contracts for public improvements; and the query thus raised is whether such a provision throws the cost of repairs upon the property paying the assessment, contrary to the established rules. The decision of this question is uncertain, some opinions being favorable and some adverse. In Kentucky (1896) it was held that, under the authority to assess the cost of paving, a provision for maintenance for five years at the contractor's expense cannot stand, "because such provision increases the burden of the property holders by adding the cost of repairs, for which the city itself is liable"; but the assessments may be enforced to the extent of the actual cost of the improvement, if maintenance provision is separable.[4] California (1893) decided a contract requirement that the pavement should be kept in repair at his expense, for five years, vitiates the assessment even if the contractor can testify that this requirement did not enhance his bid. "It was suggested that this requirement was intended as a guaranty that the work should be so well done * * * as not to require repairs"; but "the lot owner cannot be made to pay for such guaranty."[5] New York, in 1890, also decided a similar case adversely;[6] but, in 1892, its decision was that where the contract provided that the work should be done "in such a substantial manner that no repairs should be required for five years," and in case repairs became necessary the contractor should make them without further charge, this provision is to be considered a mere "guarantee of the quality of the work" and so valid.[7] The Missouri Supreme Court, too, although on this particular question at first dividing equally in their opinion (1895),[8]

[1] *Engineering Record*, Vol. xxxv, p. 178.
[2] 16 N. Y. Supp., 97.
[3] 65 Pa., 146, 156.
[4] 35 S. W. Rep. (Ky.), 1125.
[5] 98 Cal., 10, 12.
[6] 56 Hun (N. Y.), 81.
[7] 66 Hun (N. Y.), 179.
[8] 131 Mo., 27.

yet in a later case a majority holds a maintenance clause valid as really being "but an agreement to construct in the first instance a pavement good for five years."[1] Illinois by a late decision[2] (1896) strongly approves the same position, upholding a five-year maintenance by considering it "merely a warranty or guaranty of the fitness of the material for the use intended."[3]

28. Limitation to a Fixed Percentage of the Tax Valuation of Property; Default in Payments.—Frequently there is a legal provision that a special assessment cannot, in any given case, exceed a certain percentage of the tax valuation of the property. In the absence of such requirement, its validity is not affected by the fact that the assessment is greater than the tax valuation of the lots.[4] When there occurs such a limitation, the assessment is "void as to the excess only."[5] Where the law provides that the assessment on a lot shall not exceed one-half its tax valuation, it was held that the lot was liable to this maximum limit for each assessed work, although it had been assessed for other work previously in the same year.[6] Probably the failure at times to collect, in many cities, a considerable proportion of local assessments (which were depended upon to satisfy city bonds issued for the improvements) furnishes the best reason for a restriction in the amount that can be levied. The cities of New York and Brooklyn are pertinent examples. In the former, under the rule of the "Tweed ring," extravagant and unnecessary improvements were made, apparently for the purpose of personal gain to political favorites contracting. Assessments beyond all reasonableness and justice were levied upon property, until, under the excessive burden, default in the payment of assessments due amounted (according to Rosewater)[7] to nearly $8 500 000 in 1880. The same reference gives the deficit of Brooklyn, for the same date, as over $5 500 000, which the city comptroller states resulted from "fraudulent and unnecessary local improvements forced upon the owners at a time when labor and material brought the highest prices; * * * when contractors and many city officials became rich, while property owners and the city became poor." Among other municipalities wrestling with similar defaults, the condition of the cities mentioned in Section 17 furnishes examples of the same difficulty even more serious in its results.

The Validity of Improvement Bonds.

29. Import and Governing Principles.—This subject, vital to investors, is of more than passing interest to the engineer, as frequently the

[1] 38 S. W. Rep. (Mo.), 458.
[2] 161 Ill., 16, 20.
[3] See, also, the last section of Chapter vii of Exhibit.
[4] 74 N. Y., 95.
[5] 55 Ark., 148, 149.
[6] 99 Cal., 294.
[7] Columbia College Studies in History, Economics and Public Law, 2, 3, pp. 73–78.

successful prosecution of public works with which he is connected depends directly upon the validity of bonds issued for their construction. Yet the subject can here be considered only in a most general way because in its entirety it extends over so broad a field and in its details through such extensive ramifications and intricacies of general law and special enactment that it would be very inappropriate to this paper. Considering the governing principles, it may be said in the first place, that the constitutional limitations given in Section 1 (except the fourth and eighth) apply here with equal force; in fact, the fifth and sixth restrictions are especially applicable to this question, safeguarding private rights where possibly selfish interest might otherwise inflict injustice. For example, the constitutional clause providing that no "law impairing the obligation of contracts" shall be passed disables a city from retaining out of the interest of municipal bonds, as it becomes due, a tax levied by the city on such debt.[1] And the further provision against abridging the "privileges and immunities of citizens" was held to debar a discriminating tax against non-residents of a state.[2] Concerning the issue of such bonds, the essential elements already given[3] as governing valid procedure in inaugurating public improvements hold also, in general, for the legal issue of improvement bonds. The authority to issue them must be expressly granted, necessarily implied, or absolutely essential to the purposes of the municipality as declared by the Legislature; and the procedure specified and the restrictions imposed must be faithfully observed.

30. Validation Recitals and Irregularities.—The municipality has no power to validate, but the Legislature may legalize, municipal bonds (that were invalid when issued) by its sanction[4] or even by recognition made by implication.[5] A recital on the bonds, declaring that conditions precedent have been complied with, will hold the city[6] when made by officers authorized to so certify,[7] and when the holder of the bonds (purchased by him for a valuable consideration before due) has no notice of irregularity either from its appearing on the face of the bonds[8] or from some public record with notice of which he is affected,[9] even when irregularities exist; but an issue, illegal because of such irregularities, may be ratified by the municipality if it receives and keeps the proceeds of the sale,[10] or if it submits to taxation to pay the obligation,[11] thus holding the city to the debt. Generally, however, where irregularities occur, the municipality can make a successful defence against payment, as the holders of bonds

[1] 96 U. S., 432.
[2] 12 Wall. (U. S.), 418.
[3] See Sections 11 and 13.
[4] 112 U. S., 261.
[5] 5 Wall. (U. S.), 194.
[6] 107 U. S., 529.
[7] 92 U. S., 484.
[8] 110 U. S., 162.
[9] 103 U. S., 562.
[10] 94 U. S., 202.
[11] 96 U. S., 675.

are charged with a knowledge of the statutes and other public records under which the bonds are issued[1] and of the powers of the officers issuing them.[2] Furthermore, bonds that are absolutely void (because violating the constitution or statute, or for entire absence of power to issue) have no validity even in the hands of those purchasing in good faith;[3] for example, bonds issued in excess of the statutory limit are absolutely void and cannot be recovered upon.[4]

31. The foregoing legal discussion has been written with the purpose of stating and illustrating governing legal principles, the apprehension of which is essential to a general discussion of special assessments. This Appendix is, in no sense, an exhaustive treatise extending to details and peculiarities of the different state laws and policies. In any case, then, where specific legal questions arise there should be secured the opinion of legal counsel, and in no investigation is this more necessary than in the difficult and intricate considerations involved in the determination of the validity of improvement bonds. Although legal questions are for lawyers, the legal principles governing special assessment laws and procedure affect so vitally the whole consideration that the interest and value of this discussion to the civil engineer would be much curtailed without their incorporation. Nor, without them, would this paper have the completeness that a monograph on special assessments should have, and which is here especially desirable as the subject seems to have received, heretofore, but scant attention outside of legal books and none at all in engineering literature, considering the subject broadly in theory and practice. While confining the legal part of the discussion to governing principles, it has been the endeavor to make it as adequate and compactly complete as practicable. To this end many standard legal works have been consulted, the most important of which are "Dillon's Municipal Corporations," "Cooley on Taxation," and "Beach on Public Corporations." These, with the almost endless state and federal Supreme Court reports, furnish the authorities to whose profound research the author offers acknowledgment of substantial aid.

EXHIBIT.

The following transcript is from the Charter of the City of Milwaukee, 1895. It was originally framed in 1874, but is modified by whatever amendments have been passed since. It thus has been proved by the experience of more than a score of years and perfected as has been found desirable. The author has labored (in the "Present Practice of Fifty Cities" and "Procedure in their Levy

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[1] 147 U. S., 230.
[2] 111 U. S., 83.
[3] 105 U. S., 667.
[4] 102 U. S., 278.

and Collection," especially), under the necessity of giving methods and principles in the most general form; and it is believed that it will add definiteness and interest to include pertinent paragraphs giving exactly the details of procedure in a typical case. The provisions of the charter of this Wisconsin city are thoroughly illustrative of the practical rules under which its own particular methods are applied; and only those portions that are important and directly pertinent have been incorporated.

CHAPTER VII.—CITY IMPROVEMENTS AND SPECIAL ASSESSMENTS.

Section 1 provides for the general control of the board of public works.

"Section 2. The grading, graveling and planking, macadamizing or paving to the center of any street or alley, and the grading, graveling, macadamizing, planking, paving, sodding and curbing of any sidewalk, and the paving of any gutter, shall be chargeable to and payable by the lots fronting or abutting upon such street, alley or gutter, or fronting, abutting or adjacent to such sidewalk, to the amount which such grading, graveling, macadamizing, planking, paving, sodding and curbing shall be adjudged by said board to benefit such lots. The expense of all such improvements or work across streets at their intersection with streets and alleys, excepting sidewalks, and the expense of all such improvements or work across public grounds, and to the middle of streets and alleys adjacent to public grounds, and the construction of all cross-walks, shall be paid out of the fund of the ward in which such improvements are made or such works are done. After a street, alley or gutter has been constructed to the grade established by the common council, and graveled, planked, paved or macadamized in compliance with the order of the proper city authorities, the expense of maintaining, renewing, repaving, keeping in repair and cleaning such street, alley or gutter, and the pavement or other surface thereof, and of any other subsequent improvement of such street, alley or gutter, shall be paid out of the fund of the ward in which such work is done or such improvement is made; provided, however, that when a street or alley which has been graveled, planked or macadamized is ordered to be paved, the expense of such paving shall be chargeable to and payable by the lots fronting or abutting upon such street or alley to the amount which such paving shall be adjudged by said board to benefit such lots as hereinbefore provided for the improvement of a street or alley; and further provided, that when any change in the grade of any street or alley shall be ordered, the expense of cutting or filling incurred by such change of grade shall be chargeable to and paid by the lots fronting or abutting on the street or alley of which the grade shall be so changed; and provided further, that the provisions of this section in relation to the maintaining, renewing, repaving, keeping in repair and cleaning of streets, alleys and gutters shall not apply to the laying, relaying, cleaning, sodding, curbing, repairing or grading of sidewalks."

Sections 3, 4 and 5 concern assessments for canals, docks and dredging.

"Section 6. Whenever the board of public works shall deem it necessary to grade or otherwise improve any street, alley, sidewalk or public ground, or to erect and construct a bridge or viaduct over any ravine in said city of Milwaukee, or to dredge or dock any of the rivers or of the public canals after their first construction, or to abate any nuisance caused by stagnant water in said city, it shall cause to be made an estimate of the cost of such work, and shall put the same on file in its office, and such estimate shall be open to the inspection of any party interested. Thereupon the said board of public works shall make to the common council such recommendation in relation to the proposed work as it may deem proper; and upon the same being adopted by the common council, in whole or in part, the said board may order so much of the work to be done as shall have been adopted, provided that no change of any previously established grade, and no such work, chargeable to lots and parcels of land fronting on or abutting on the same, except the grading, graveling and paving of streets, the paving of gutters and making of sidewalks, and except repairs, and docking and dredging, shall be ordered by resolution, ordinance or otherwise, unless a petition therefor shall first be presented to the common council, signed by residents of said city owning a majority of the feet in front of all the lots fronting upon such proposed improvements, owned by residents of such city, and for that purpose every person in the actual possession of any lot or parcel of land fronting upon such improvements, under contract in force for the purchase thereof from the owner, shall be held to be a freeholder within the meaning of this act, and to be the owner of such real estate for the purpose of petitioning as the owner thereof. Each person signing such petition as a resident or as the owner of property, shall be required to write after his signature thereto a brief description of the property so owned by him, and of the place of his residence in said city, and to annex thereto an affidavit that he is such resident and owner, and thereupon he shall be taken to be such resident and owner, and such petition shall be as valid and have the same effect as if such person were the owner of such property, and a resident of the city or ward, as stated in his affidavit, although, in fact, it should thereafter appear that he was not such owner or resident. The common council may order the grading, graveling and paving of streets and alleys, the paving of gutters and the making of sidewalks, without such petition, provided, however, that in the absence of such petition, the resolution of the common council ordering the work shall have been referred by the council to a special committee of five members, no one of whom shall be a resident of the ward or any ward in which the grading, graveling or paving of streets, alleys or gutters, or the making of sidewalks, mentioned in the resolution, is proposed to be done, and shall have been reported by such committee to the common council with their recommendation that it be adopted, before a vote shall be taken upon its adoption, and provided such resolution shall declare why it is necessary for the public interest to proceed without such petition, and shall also, upon its passage, be supported by the votes of three-fourths of all the aldermen elected, and of a majority of the aldermen of the ward or of each ward in which such grading, graveling or paving, or making of sidewalks is to be done; and provided, further, that no such resolution ordering the grading, graveling or paving of a street or streets or alley, the paving of gutters or the making of sidewalks without a petition therefor shall be voted upon or passed at any meeting of the common council held within four weeks from the time of its

presentation to the council, and the vote on its passage shall be taken by yeas and nays, and duly entered in the journal of proceedings. Provided, further, that whenever the board of public works shall deem it necessary to pave or otherwise improve any street, alley or gutter, or any part of any street, alley or gutter, after the same has been once constructed to the grade established by the common council, and graveled, planked, paved or macadamized, the expense of maintaining, renewing, repairing or repaving whereof shall be a lawful and proper charge against the funds of the ward in which such street, alley or gutter is situated, and a majority of the residents of the said city of Milwaukee owning a majority of the feet in front of all the lots fronting on such proposed improvement, owned by residents of such city, shall file a petition with the said board for any pavement or other improvement deemed by said board to cost more than the estimate made by the board, of the cost of improving said street, alley or gutter, said cost to be determined by said board, it shall be the duty of said board and of the common council to grant the request of such petition, and to proceed to repave, or otherwise improve, said street, alley or gutter, or any part thereof, named in said petition, according to the prayer of the petition, in the same manner as said board and council are now required to maintain, renew, repair or repave any such street, alley or gutter; provided, however, that all cost and expense of such repavement, or other improvement, in case of such petition, in excess of the estimated cost of the work, made and filed in the office of the board of public works, for the improvement of said street, alley or gutter, or part thereof, shall be chargeable to, and be made payable by, the lots fronting or abutting upon such street, alley or gutter, or part thereof, such excess to be apportioned by such board to said lots respectively, in proportion to the benefits adjudged by said board to have been conferred by said repavement, or other improvement, in the same manner that the original improvement of streets, alleys and gutters are now lawfully chargeable to, and made payable by such lots; provided, further, that the petition for such repavement, or other improvement, required in this act, as a condition of increased cost, shall, as to form, qualification of petitioners and otherwise, conform to the requirements in case of petitions for other work chargeable to lots, and requiring a petition therefor, as provided in said Section 20, Chapter 324, Laws of 1882, of which section this act is in part amendatory."

"Section 7. Before ordering any work to be done by the owners of lots or lands fronting on the same, said board shall view the premises, and consider the amount proposed to be made chargeable against said several lots or pieces of land, and the benefits which, in their opinion, will actually accrue to the owner of the same in consequence of such improvement, and shall assess against the several lots or pieces of lands, or parts of lots or pieces of lands, which they may deem benefited by the proposed improvement, the amount of such benefit which those lots or pieces of land will severally, in the opinion of said board, derive from such improvement when completed in the manner contemplated in the estimate of the cost of such work, made as provided by section six of this chapter, taking into consideration in each case any injury which, in the opinion of the board, may result to each lot or piece of land from such improvement; and in case the benefits, in their opinion, amount to less than the cost of the improvement, the balance shall be paid out of the ward fund of the ward or wards in which such improvement is made; and said board shall endorse their decision and

assessment in every case on the estimate of the cost of such improvement filed in their office."

Section 8 provides for damages resulting from the change of an established grade.

"Section 9. As soon as any assessment of benefits or damages, or both, shall be made, as in the preceding sections of this chapter provided, the said board shall give notice to all parties interested, by advertisement for not less than four days in the official papers of the said city, that such assessment has been made and is ready for inspection in its office, and that the same will be open for review and correction by the said board, at its office, for not less than four days after the first publication of such notice during certain hours, not less than two hours of each lay day, and that all persons interested will be heard by said board in objection to such assessment, and generally, in the matter of such review and correction. It shall be sufficient to state in such notice, in brief, what such assessment has been made for, and in what locality, and no further notice or publication of such assessment shall be necessary. During the time mentioned in such notice, the said board shall hear objections and evidence, and they shall have power to review, modify and correct such assessment, in such manner as they shall deem just, at any time during such review, and for three days thereafter; and thereupon said board shall endorse such corrected and completed assessment upon or annex the same to the estimate of the cost of such improvement, made and filled in its office, as provided in section 6 of this chapter, and shall file a duplicate of such estimate and assessment in the office of the city clerk, who shall lay the same before the common council at its next meeting; and, thereupon, the common council may confirm or correct said assessments, or any of them, or may refer the same back to the board of public works for revision and correction; and the said common council, and the said board of public works, shall respectively have the like powers, and perform the like duties, in relation to such assessment, and any subsequent assessment made pursuant to such reference by the common council, as are prescribed and conferred in relation to the first assessment."

"Section 10. Thereupon, as soon as the common council shall have confirmed such assessments of benefits and damages, the said board shall enter into a contract for the doing of the same, as hereinbefore provided. Such contract shall require the contractor to receive certificates upon or against the several lots, parts of lots, or parcels of land, which may be assessed with benefits on account of the same, to apply in payment of the contract price, as now provided by law; provided that in any case where the contract price of the work to the center of the street or alley, done opposite to any lot or parcel of ground, shall exceed the benefits assessed to such lot, the excess shall be paid out of the ward fund of the ward in which such lot, part of lot or parcel of land shall be situated."

"Section 11. The owner of any lot, or tract of land, or tenement, who feels himself aggrieved by such assessment, as confirmed by the common council, as to the amount of benefits thereby adjudged to accrue to him by reason of any improvements charged against his lot or parcel of land, or the amount of damages, costs and charges, arising to such owner from an alteration of grade, may, within twenty days

after such confirmation by the common council, appeal therefrom to the circuit court of Milwaukee county. * * * Such appeal shall not affect the rights of the contractor, or the proceedings in reference to his contract, but the certificate against the lot or parcel of land in question shall be given as if no appeal had been taken; and in case the appellant shall succeed, the difference between the amount charged in the certificate and the amount of the benefit finally adjudged shall be paid by the city out of the proper ward fund to the appellant, but not until he shall have done the work in question, or have paid the certificate issued for doing the same." * * *

"Section 12. The appeal given by the last preceding section, from the assessment of the board of public works, as confirmed by the common council, to the said circuit court, shall be the only remedy for the recovery of any damages, costs and charges arising from any alteration of grade by the said city, or sustained by reason of any proceedings or acts of the said city or its officers, in the matter to which such assessment of damages or benefits relates; and no action at law shall be maintained for such damages or injuries, whether arising from an alteration of grade or otherwise."

Sections 13, 14, 15, 16, 17, 18, 19, 20 and 21 concern minor details of certificates for work done, cleaning, repair, nuisances, etc.

"Section 22. Whenever a petition shall be presented to the common council, signed by a majority of the owners of lots or parcels of land, fronting or abutting on any street, or part of a street, actually residing on such lots or parcels of land, and approved by a majority of the aldermen of the ward or wards in which such street or part of such street shall be located, requesting such or part of such street to be sprinkled, the common council shall order the board of public works to advertise for sealed proposals for sprinkling such street or part of such street. Such advertisement shall be published for at least six days in the official city papers, and shall state the street or part of the street to be sprinkled, and for what length of time. All contracts shall be awarded by said board to the lowest bidder in compliance with the provisions of section 10 of chapter 5 of this act, and shall be expressly subject to the powers given to said board by said chapter."

"Section 23. The board of public works shall assess against the several lots, parts of lots or parcels of land, fronting or abutting on such street, or part of such street, the cost of sprinkling such street, or part of such street, in front of such lots, parts of lots, or parcels of land. The cost of sprinkling such street, or part of such street, at its intersection with streets and alleys, and across public grounds, and to the middle of such street, adjacent to public grounds, shall be paid out of the fund of the ward in which such work is done."

"Section 24. After the completion and performance of any contract for sprinkling entered into by the board of public works for work chargeable to lots or lands fronting on streets or alleys upon which such work has been done, the cost of such work shall in the first place be paid out of the ward fund of the proper ward.

"It shall be the duty of the said board to keep a strict account of the cost of such work done in front of such lot or parcel of land, and report to the city comptroller on the completion of each such contract, stating and certifying the description of the lots, parts of lots or

parcels of land, in front of which work chargeable thereto under such contract has been done, and the amount chargeable to each such piece of property, and the said comptroller shall, at the time of making his annual report to the common council of the lots or parcels of land subject to special tax, or assessment, include therein the said lots or parcels of land so reported to him by said board of public works, with the amount chargeable thereto for sprinkling, done under such contracts, during the preceding year; and such amounts shall be levied on the lots or parcels of land, respectively, to which they are so chargeable, in like manner as other special taxes are levied in said city, and when collected the same shall be credited to the ward fund in which such property is situated."

The remaining sections of the chapter contain, among other things, provisions permitting lot owners (who agree to waive irregularities that may occur in the assessment) to apply to the board of public works for permission to pay such assessment in annual installments (extending over a period of from five to ten years) instead of at once, in which case "street improvement bonds" are issued against the lots petitioning, which the contractor binds himself to accept in payment for his work, and which are first liens. These installments are entered upon the annual tax roll instead of the total amount as is otherwise done, but the landowner has still the privilege of paying at any time the total amount still due, with accrued interest. Another provision is as follows:

"No special assessment or certificate thereof or tax sale certificate based thereon shall be held to be invalid for the reason that any contract which has been heretofore or may hereafter be let contains on the part of the contractor a guarantee or any provision to keep the work done under such contract in good order or repair for a limited number of years, when such guaranty or provision was inserted therein for the purpose of insuring the proper performance of such work in the first instance. All such provisions in contracts for doing public work, inserted for the purpose aforesaid, are hereby legalized, and all such provisions shall be deemed *prima facie* to have been inserted for that purpose, unless the time during which the contractor is required to keep the work in good order or repair shall exceed five years."

CHAPTER VIII. SEWERS.

Sections 1, 2 and 3 provide for sewerage districts, plans and diagrams, and publication of notice and hearing of objections.

"Section 4. The said board may reconsider and modify said plan, and at the expiration of ten days after the time such notice shall have been given to said resident freeholders of the district, shall report such plan to the common council for its approval."

"Section 5. The common council shall take such plan into consideration, and, within thirty days after receiving the same, shall return it to the board approved; or, if objected to, with a statement in writing of such objections, or of any alteration or improvements thereof which they may deem desirable."

"Section 6. The said board may, on return of such plan by the common council, modify or change the same in accordance with the

suggestions of the common council, or may prepare a different plan, which shall be again submitted to the common council, and may generally modify and change their action in the premises, until a plan shall be mutually agreed upon by the board and common council; provided that no plan shall take effect until approved by the common council, and no plan thus approved shall be deviated from except by consent of the common council; and provided further, that sewers may be ordered and constructed in any district without the plans of such district being completed in their whole extent and all their details."

Sections 7 and 8 require the board of public works to report annually the sewers necessary, etc., and cover the details of letting the contract.

"Section 9. Such contracts shall require the contractor to receive as payment for so much of the work as has been assessed against the lots opposite to the front of which any sewer shall extend certificates against such lots respectively; and the residue of such contract shall be paid out of the proceeds of the general sewerage tax, to be levied on the real estate and personal property within the sewerage district by the common council, on the recommendation of the board of public works."

"Section 10. After any contract for work under this act, to be paid for in whole or in part by special assessments, shall have been entered into, the board of public works shall make, or cause to be made, an assessment against all lots, parts of lots and parcels of land, fronting or abutting on the work so contracted to be done, on each side of the same for its whole length, and which have not before been so assessed for sewerage purposes, at the rate of eighty cents per lineal foot of the whole frontage of each lot, part of lot or lots, or parcel of land, fronting or abutting on either side of such sewer, except corner lots, which shall be assessed therefor as follows: Corner lots, not subdivided in ownership and subdivisions of corner lots, constituting the actual corner of corner lots subdivided in ownership, shall be entitled to deduction, in making such assessment, of one-third from the aggregate of the street lines of such corner lots, or corner subdivisions thereof, on all the streets in front thereof; such deduction to be made in the assessment of the longest street line of such corner lots, or corner subdivisions thereof, or in case of equal street lines thereof, in the assessment for the second sewer to which they are liable; provided, however, that when the actual cost of any sewer shall be less than one dollar and sixty cents per lineal foot, then, and in that case, the assessment shall be for the actual cost of such sewer per lineal foot, one-half thereof to be chargeable against the property fronting or abutting thereon, on each side thereof. Whenever any lot which, as originally planted, fronts or abuts on any sewer, is subdivided, and the subdivisions thereof are owned by different persons, no subdivision of such lot, not fronting or abutting on such sewer, and not owned by the same persons who owns the subdivision fronting or abutting on such sewer, shall be assessed for the cost of such sewer."

Section 11 concerns further details of subdivisions.

"Section 12. The cost of all sewers in street and alley crossings, and of all sewers, in excess of one dollar and sixty cents per lineal foot, chargeable to lots and lands, as provided for in section ten of

this chapter, of all catch basins for receiving the water from the gutters, and of the overflow pipes connecting them with the sewers, of all temporary catch basins, and of the repairing and cleaning of sewers, and all expenditures for temporary work necessary to carry out the system of sewerage herein provided, and all costs for constructing sewers, not provided for by special assessment, shall be paid out of the fund of the proper sewerage district; and all cleaning and repairing of sewers and catch basins, and all temporary work necessary to be done as above stated, shall be done by the authority of the board of public works, as may be necessary."

"Section 13. The board of public works shall report to the common council, on or before the 15th day of December in each year, as accurately as may be, the amount of money required for sewerage purposes for the ensuing year, in each district, in addition to the special assessments made; and the common council are hereby authorized to direct the levy and collection of a tax for sewerage purposes in each district, for such amount as may be necessary, not, however, to exceed in any one year the sum of one and one-half mills on the dollar, on all the property, real and personal, subject to taxation within any such sewerage district, which tax, so levied, shall, when collected, be paid into the city treasury, and be placed in the fund of the sewerage district in which the same has been collected; and the city comptroller is hereby directed and required to keep a separate and distinct account with each sewerage district. The tax to be levied under the provisions of this section may be added on the tax roll to the general city tax assessed against such property."

The remaining sections of the chapter concern minor details.

Chapter X.—Water-Works.

Sections 1, 2, 3, 4, 5 and 6 concern the control of the water-works by the board of public works in general matters.

"Section 7. There is hereby created for the said city a separate fund, to be called the water fund. There shall belong to such fund all bonds and proceeds thereof, authorized by law to be issued for the construction of the said water-works, all proceeds of all taxes levied for the construction of the said water-works, all water rates assessed and collected for water proceeding from such water-works, and all other proceeds, revenue and income of said water-works, and all other moneys and property in any way derived by the said city in aid of the said water-works, or appropriated by the said common council toward the same; and the said fund is hereby exclusively devoted and appropriated to the construction and maintenance of the said water-works, and to the payment of said water bonds, until the said works shall be wholly completed and the said bonds wholly paid. Said water fund shall be kept in the city treasury in the custody of the city treasurer, and shall be disbursed by him on vouchers drawn for the same in the manner provided in this act; and said city treasurer and the sureties on his official bond shall be liable for the safe keeping and disbursement thereof. It shall be the duty of the treasurer of said board of water commissioners to submit his account of the water funds in his hands on the first day of January, 1875, or at such time as the water-works shall be surrendered, as provided in section one of this chapter, and to settle and adjust such accounts with the city

comptroller, and to pay over any balance remaining in his hands on that day to the city treasurer, to the credit of the water fund."

Sections 8, 9, 10, 11, 12, 13 and 14 provide for rules and regulations, reports, protective ordinances, and making the water rates collectable "in the same manner as other taxes on real estate are collected."

"Section 15. The board of public works for the city of Milwaukee, before laying water pipe along a street, alley, or other line in said city, shall assess against the several lots, parts of lots or parcels of land which may front or abut on the proposed line of water pipe, or which may be contiguous to and used in connection with any lot or parcel of land so fronting and abutting, the amounts which the said several lots, parts of lots or parcels of land may, in the judgment of the said board, be specially benefited by reason of laying such water pipe, not to exceed, however, the amount prescribed in the next section; provided, that no lot, parcel of land or part thereof, shall be subjected to the payment of more than one assessment for water pipe laid in the same street or alley."

"Section 16. A regular lot (not corner) which may front or abut on the line of water pipe, shall be assessed an amount equal to one-half of the cost, as estimated by the said board of public works, of furnishing and laying a regular minor water pipe of approved materials and manufacture, with the required openings for connections with private service water pipe along the front of such lot, such minor pipe to be not less than four nor more than six inches in diameter, as the said board may determine. Every irregular lot, part of lot, or other parcel of land fronting or abutting on such line of water pipe, and likewise any parcel of land, or lot, which shall be contiguous to any parcel of land, or lot, or part of lot so fronting or abutting, and which in the judgment of the said board is or may be most advantageously used in connection therewith, shall be assessed for such water pipe, the amount which, in the judgment of said board, shall be as nearly as may be in just proportion to the amount assessed for regular lots as compared with the special benefits derived by each from the laying of the said water pipe."

Sections 17 and 18 concern corner lot rebates, apportionment to subdivided lots, and the levy and collection "as other special assessments are levied and collected in said city."

"Section 19. The said board of public works shall file reports of such assessments with the comptroller, who shall record the same in a book to be kept for that purpose, and give notice thereof to the parties interested, by publishing the same for three successive days in the official papers. Any person feeling himself aggrieved by the report of said board, may, within twenty days after the completion of the publication of notice by the comptroller, appeal from such report to the circuit court of Milwaukee County. Such appeal shall be entered and conducted in like manner, and like security for costs shall be required as provided by law in cases of appeal from the decision of the common council of said city to said court, on the returns of assessments of benefits for street improvements. In the making and signing of all reports or returns, under this chapter, by the said board of public works to the comptroller or any other officer of said city, the official signatures of the president and secretary of said board shall be sufficient."

"Section 20. The said board of public works shall, from time to time, make reports to the comptroller of all work done, for which assessments shall have been made, as hereinbefore provided, and the comptroller shall file such reports, and enter the same in his book of records of assessments; and of all assessments for work so reported to have been done, the comptroller shall, if possible, make certified returns to the city clerk, in time to have the same included in the tax levy for the current year; and the same shall be entered on the tax roll in a separate column, under the head of 'water pipe assessments;' and the same shall be collected, and the payment thereof shall be enforced by sale, deed, and other proceedings, in like manner as is now provided by law in case of assessments for street improvements. No certificates shall be issued by the comptroller for such assessments, but all such assessments and the proceeds thereof, when collected, shall belong to the fund for the construction of water-works, and shall be credited to said fund on the books of the comptroller and treasurer of said city."

The remaining sections provide details of administration, etc.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

PRESSURES RESULTING FROM CHANGES OF VELOCITY OF WATER IN PIPES.

By J. P. FRIZELL, M. Am. Soc. C. E.

TO BE PRESENTED OCTOBER 6TH, 1897.

The pressures that may be generated in pipe lines by the sudden closing of valves or the sudden starting of pumps have long occupied the attention of hydraulic engineers, and some attempts have been made, both experimentally and analytically, toward a better understanding of the subject.

Edmund B. Weston, M. Am. Soc. C. E., presented to this Society, in 1884, an account of some experiments made upon water pipes at Providence, R. I., with the view of ascertaining the maximum pressure incident to the sudden stoppage of water in a pipe.* The pipes were short and of small diameter. The pressures were recorded by a style which drew a straight mark upon stationary paper, and the diagram took no account of the oscillations which succeeded the main shock incident to the stoppage of the current. The valve which

* See *Transactions*, Vol. xiv, p. 238.

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

caused the stoppage occupied an appreciable time in closing. The results, though praiseworthy as an attempt at the elucidation of an important subject, are of limited practical value.

A somewhat higher degree of value can be accorded the work of Professor R. C. Carpenter, of Sibley College, Cornell.* In this case the style recorded the pressures on paper moving isochronously, and represented the oscillations succeeding the main shock. The pipes used were of small diameter and only a little over 50 ft. in length, being, according to what follows, much too short to fully develop the pulsation incident to closing the valve, especially when the closing is far from being instantaneous. Professor Carpenter adds some theoretical discussion, which displays a comprehension of the elements of the question.

Professor I. P. Church has published a paper† aiming to treat the whole question in a rigorously exact manner, determining the pressure and velocity in the pipe for different positions of the valve while closing. The results are complex and intricate. The writer makes

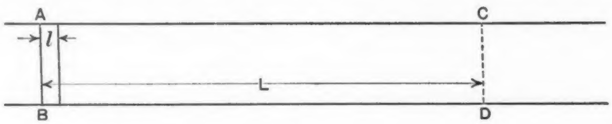

FIG. 1.

no practical application of them, and regrets his inability to pursue the subject further.

Recently this subject has been brought into renewed prominence from its connection with the regulation of water-wheels drawing through long penstocks, and from the further fact that the requirements of electric transmission call for greatly increased exactness in the regulation of wheels. Feeling that anything tending to a better understanding of the subject would be acceptable under present conditions the author is emboldened to offer the following views:

Assume a long pipe filled with water (Fig. 1). Imagine at $A\ B$ a piston to start forward. When it has moved the distance l, it has set the water in motion as far as $C\ D$.

Let $r =$ radius of pipe in feet.

Let $W =$ weight of a cubic foot of water in pounds.

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* Published in the *Transactions* of the Am. Soc. M. E., Vol. xv.

† See the *Journal* of the Franklin Institute, April and May, 1890.

Let m = modulus of elasticity of water = 20 000 atmospheres, say 294 000 lbs. per square inch.

Let M = modulus of elasticity of metal of pipe, in pounds per square inch.

Let T = thickness of pipe metal, in inches.

Let t = time occupied by the piston in moving the distance l, in seconds.

Let f = force exerted upon the water by the piston, in pounds per square inch.

When the piston has moved a distance l, although it has only moved the center of gravity of the mass L, a distance $\frac{1}{2} l$, it has done work in compressing the water and distending the pipe equivalent to moving the mass a distance l, and imparting to it a velocity $\frac{l}{t}$. This will appear on reflecting that, if the compression and distension could be released without any further obstruction to movement, the mass of water would have the motion stated.

The increase in the radius of the pipe from the pressure f is $\frac{r^2 f}{M T} = \Delta r$.

Increase in cross-section $= 2 \pi r \Delta r = 2 \pi \frac{r^3 f}{M T}$.

Increase of volume $= L f \frac{2 \pi r^3}{M T}$.

Traverse of piston due to distension of pipe $= L f \frac{2 r}{M T}$ ....(1)

Traverse of piston due to compression of water $= \frac{L f}{m}$ ....(2)

Total traverse of piston in time $t = l = L f \left(\frac{2 r}{M T} + \frac{1}{m}\right) \therefore$

velocity $= \frac{L f}{t} \left(\frac{2 r m + M T}{m M T}\right)$ ....(3)

The total weight of water set in motion is $\pi r^2 L w$.

The force acting to impart motion is $144 \pi r^2 f$ pounds.

Gravity acting freely would impart to this mass a velocity of $g t$ feet per second in the time t. Therefore there results the proportion

$$\frac{l}{t} : g t = 144 \pi r^2 f : \pi r^2 L W$$

whence

$$L = 144 f \frac{g t^2}{l W} = 144 \frac{g t^2}{W} \frac{1}{L} \frac{m M T}{2 r m + M T} \text{ ....(4)}$$

and the velocity of pulsation in pipe is

$$\frac{L}{t} = \sqrt{144 \frac{g}{W} \frac{m M T}{2 r m + M T}} \quad \text{.................................(5)}$$

Assuming a 60-inch pipe of steel ¼ in. thick, $T = \frac{1}{4}$, $M = 30\ 000\ 000$, there results $v = 4\ 272$ ft. per second.

If the distension of the pipe is neglected by assuming an infinite value for M, (5) may be put in the form.

$$\frac{L}{t} = \sqrt{144 \frac{g}{W} \frac{m}{\frac{2 r m}{M T} + 1}}.$$

The assumption that no distention of the pipe takes place is equivalent to making M equal to infinity. On this assumption the above equation becomes

$$\frac{L}{t} = \sqrt{144 \frac{g}{W} m} = 4\ 672 \quad \text{..................................(6)};$$

being substantially the velocity of sound in water, which is usually taken at about 4 700 ft. per second.

Instead of the supposition of a piston suddenly starting forward, imagine water, moving with a uniform velocity v, to be suddenly arrested by the closing of a gate. Then the force f is the force acting against the gate and walls of the pipe, in excess of the static pressure, and is found thus: Let X be the length of the pipe, and for simplicity suppose X to exceed $\frac{L}{t}$ or the value of L when $t = 1$. In one second after closing the gate, the length L is condensed into the length $L - v$, and the diminution of volume by compression is represented by $\frac{v}{L} \frac{M T}{2 r m + M T}$ and

$$f = \frac{v}{L} \frac{M T m}{2 r m + M T} \quad \text{.................................(7)}$$

Taking $v = 4$ ft., the other symbols as before, then $L = 4\ 272$

$$f = \frac{4}{4\ 272} \frac{7\ 500\ 000}{5 \times 294\ 000 + 7\ 500\ 000} \times 294\ 000$$

$= 230$ lbs. per square inch.

It will appear from (6) that f is theoretically independent of the length of the column of water in motion, *i. e.*, the length of the pipe. This, however, involves the assumption that the stoppage is absolutely instantaneous. Under practical conditions, in which the stoppage occupies an appreciable time, the force developed is not independent

of the length. For the purpose of experiment, a form of valve may be adopted, causing an instantaneous stoppage, though such valves are ordinarily avoided. Assuming such a valve to be used, upon closure, the full pressure is instantly developed upon the valve. The section in which the water is coming to rest moves up stream with the velocity indicated by equation (5). The amplitude of this movement is only limited by the length of the pipe, above the valve, either to the reservoir or to the larger pipe from which it branches.

Neglecting the elasticity of the pipe, the time occupied by its contents in coming to rest is $\frac{X}{4672} = t$. The water has continued to flow into the pipe with the undiminished velocity v for t seconds after the closure. The compression of the water in the pipe is represented by $\frac{v\,t}{X}$, and the force exerted on the interior by $m\frac{v\,t}{X}$ pounds per square inch.

The pressure on the valve, however, is not released when the entire contents have come to rest. The water, now, through the entire length X is in a state of compression far above the normal, and a release and reversed motion takes place. This commences at the origin of the pipe and moves toward the valve with the velocity of equation (5). The time therefore between the stoppage and the release of pressure will be $2\,t$. If the normal static pressure in the pipe is f or more, then the pressure at the valve will fall as much below the normal at the release as it rose the same at the closure, except in so far as the movement is affected by fluid friction, and a series of pulsations with the cyclic interval $2\,t$ will run through the pipe till the movement dies out.

If the pipe branches from another of larger diameter, then, when the pulsation of closure reaches the larger pipe, it will continue through the same with diminished intensity, the pressure being proportional to the velocity. A pulsation of release will return through the smaller pipe, partially releasing the pressure on the valve. The pulsation of closure will reach the head of the larger pipe, and a pulsation of release will return through both pipes, etc. A complex system of pulsations will ensue, depending on the relative lengths of the pipes. Very different is the case when the arrest of motion occupies an appreciable time. The closing may be supposed to take place by a great number of small steps, each of which may be regarded as

instantaneous. Each step occasions a certain diminution of velocity and is accompanied by an increment of pressure. Each increment runs to the head of the pipe, is discharged and returns in the same manner and with the same velocity as before. No marked increase of pressure takes place at the head of the pipe during the closing. Every increment of pressure originating at the valve remains in force there till the pulsation has run to the head of the pipe and back to the valve.

It is now possible to perceive clearly the defects of the experiments made by Mr. Weston at Providence, and by Professor Carpenter at Cornell. In the former the valve was thought to occupy 0.15 second in closing, an interval sufficient for the pulsation to run 600 or 700 ft. The pulsation lasted as long as the closing, and its commencement had extended far beyond the limits of the pipe before the valve was fully closed. Of course, the full pressure due to the closure was not developed. To obtain this pressure the pipe should be so long that the valve is fully closed before the commencement of the pulsation reaches the head of the pipe and returns. The inquiry was further complicated by using a series of pipes of different diameters running from $1\frac{1}{2}$ ins. up to 6 ins., the longest being 75 ft.

In Professor Carpenter's experiments, first series, there was a 2-in. pipe 30 ft. long containing the valve, then 33 ft. of $2\frac{1}{2}$-in. pipe, then 150 ft. of 3-in., then 375 ft. of 6-in. In the second series there was a $1\frac{1}{2}$-in. pipe $53\frac{1}{2}$ ft. long leading from a tank. The valve was thought to occupy 0.023 second in closing, an interval long enough to allow the pulsation to run 100 ft. In none of these experiments could the full pressure due to closing have been developed. In some of the experiments an air chamber was added to the complications incident to different sizes and inadequate lengths of pipes. In all experimental inquiries, the phenomenon under investigation should be produced as free as possible from the interference and superposition of extraneous phenomena.

The preceding results appear to be all that are necessary for the case of total instantaneous arrest of motion. The closeness with which the formula, with proper modifications, represents the velocity of sound, may be accepted as a guaranty that it is well grounded. In fact, by taking the velocity of the pulsation, in all cases, equal to that of sound, the resulting error would be less than one-tenth in a 5-ft.

steel pipe, and in cast-iron pipes of ordinary size the error would be negligible for ordinary purposes.

In this case (total instantaneous arrest of motion) guidance is afforded by these considerations: The flow into the pipe continues with unabated velocity from the instant of stoppage till the arrival of the pulsation at the head of the pipe. This determines the quantity of water, above the normal, in the pipe at that instant, and its consequent condition of pressure. For any given pipe no error is made in taking the pressure consequent on the arrest of motion proportional to the velocity.

Save as to very small pipes of short length, the case of sudden and total arrest of motion is not within the range of consideration. The ordinary case is that of a gradual arrest of motion. Even in this case, the preceding results can give all the aid required for practical purposes. The general method is this : Find the interval t required for a pulsation to traverse the pipe. Then, the diminution of velocity effected during twice this interval may be regarded as a velocity instantaneously arrested, and the pressure deduced from this supposition will be the pressure resulting from the diminution of velocity.

A common question is: "What is the maximum pressure that could result from closing a pipe, in a given time, at a uniform rate ?" The velocity will diminish more rapidly as the movement proceeds, the diminution being most rapid near the close. Suppose the interval $2t$ to expire at the close of the movement. Find the position of the gate and consequent velocity at the beginning of that interval. Find the pressure P that would result from the instantaneous arrest of this velocity. A pressure very near P must have existed at the commencement of the interval $2t$. Correct the velocity accordingly, and recompute P, etc. By such methods results sufficiently correct for practical purposes can be obtained.

The most important bearing of these principles, as already indicated, is in the regulation of water-wheels supplied by long penstocks. As an instance of the difficulties liable to occur in such applications, consider the power plant of the Pioneer Electric Power Company of Ogden, Utah.*

The length of the pipe line is given as 31 000 ft., a length requiring more than 7 seconds for a pulsation to traverse, and implying a cyclic

* See *Proceedings*, May, 1897.

interval of more than 14 seconds. The pipe is designed for a maximum velocity of 9 ft. per second, the sudden arrest of which would involve, according to what precedes, a pressure above the normal of over 500 lbs. per square inch. The normal pressure in the pipe at the power house is said to be 500 ft. head, or about 217 lbs. per square inch.

In this condition suppose a sudden falling off of one-fifth in the demand for power. By suddenly diminishing the draft of water, and consequently the velocity in the pipe, by one-fifth, the pressure in the pipe is increased by 100 lbs., nearly 50%, and for a few seconds the power would be increased rather than diminished by closing the gates. Consider again the return pulsations, lowering the pressure much below the normal, and some idea is obtained of the difficulties attending the maintenance of a uniform speed under such conditions.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will hereafter be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

ISAAC WILLIAMS SMITH, M. Am. Soc. C. E.*

DIED JANUARY 1ST, 1897.

A notable figure was removed from among the engineers of the Pacific Coast by the death of Isaac Williams Smith, which occurred at Portland, Ore., January 1st, 1897.

He was born at Fredericksburg, Va., in 1826, the son of Rev. George A. Smith and Ophelia Ann Williams, the latter a granddaughter of Captain Philip Slaughter, an officer of the Revolution.

He was educated at the Fairfax Institute at Claivens and at the Virginia Military Institute at Lexington, Va., graduating from the latter with high honors in 1846, at the age of twenty.

After graduation he served for a time as assistant engineer under Captain Emory, U. S. A., on the survey of the northeast boundary. Later, receiving an appointment as second lieutenant in Company K, United States Voltigeurs, he served in the detachment under Major Lally in the war with Mexico during one campaign, and was then detailed for recruiting service and stationed at Baltimore. In 1849–50 he was assistant engineer and astronomer on the survey of the parallel between the Creek and Cherokee Indians under Lieutenants Sitgreaves and Woodruff, U. S. A. In 1851 he was assistant astronomer and first assistant on the survey of the parallel between Iowa and Minnesota, Andrew Talcott being chief engineer. In 1852 he was resident engineer on the survey and construction of the Orange and Alexandria Railroad under Chief Engineer Atkinson. In 1853–54 he was assistant engineer upon the Pacific Railroad surveys and explorations along the southern route under Lieutenants Williamson and Parke, of the Corps of Engineers, U. S. A. After a brief sojourn in California, he came north to the newly formed territory of Washington, and was engaged as engineer and special agent for the construction of lighthouses on the Straits of Fuca and Shoalwater Bay, the Twelfth Lighthouse District, under Major Hartman Bache, Corps of Engineers, U. S. A. These guides for mariners were erected at New Dungeness, Tatoosh Island and Smith's Island, on the Straits of Fuca, and at Toher Point, on the coast of southwestern Washington. This work was accom-

* Memoir prepared by D. D. Clarke, M. Am. Soc. C. E., and Messrs. Edward G. Tilton and Robert P. Maynard.

plished with considerable difficulty and peril, journeys to and from the works being made either in small rowboats or Indian canoes through waters that were of a very treacherous character, and often with only Indians for his crew.

The uprising of the Indians against the whites all over the northern country, commonly called the Yakima War, occurred during the years 1855–56, and many settlers lost their lives. An armed force was quickly raised, and in the campaign that followed Mr. Smith served as aide-de-camp on the staff of Captain I. I. Stevens, then Governor of the Territory, and in command of the volunteer forces engaged in subduing the Indians, and saw much active service. After the close of the war he was engaged for a year or two as United States Deputy Surveyor under his life-long friend, Major James Tilton, also a veteran of the Mexican War, and then filling an appointment as United States Surveyor-General for Washington Territory, and surveyed several of the meridian and standard parallel lines then being established through the trackless and all but impassable forests of western Washington. Completing this work, he was appointed Register of the United States Land Office for the Olympia District, which included the then vast Territory of Washington.

In 1862 he joined the rush that came from every point on the Pacific Coast to the newly discovered placers in Cariboo, B. C., where he remained but a short time. On his return from the mines, he went east to his native state and tendered his services to the Confederate government. Receiving the appointment of captain of engineers, later being brevetted colonel, he was continuously employed until the close of the war upon the defences before Petersburg and Richmond. After the surrender at Appomattox, he returned home, the possessor solely, as described in his own words, "of an old gray uniform, much tattered and worn, a good horse, and a large amount of experience." He soon found employment in the operating department of one of the dilapidated Virginia railroads, but in a few months, in 1866, received an appointment as division engineer on the Imperial Mexican Railroad from Vera Cruz to Mexico under Andrew Talcott, chief engineer, and was placed in charge of the line from Paso-del-Macho to Ongaba. He remained in Mexico during the years 1867–68, engaged upon this work and as chief engineer and inspector of drainage and hydraulic work near Tepic for Messrs. Barron & Forbes.

In 1869 he was again on the Pacific Coast serving as engineer on construction of the Western Pacific Railroad, later merged into the Central Pacific, and as superintendent of repairs, etc., from Sacramento to San Francisco, under S. S. Montague, chief engineer.

In 1870 he entered the service of the Northern Pacific Railroad Company under Edward A. Flint, engineer of the Pacific Division and W. Milnor Roberts, chief engineer, and was placed in charge of

surveys along the Columbia and Cowlitz Rivers in Washington Territory. After a few months of service with the Northern Pacific he was entrusted with the design and construction of locks and a canal around the falls of the Willamette River, a few miles above Portland, Ore., a work of considerable magnitude, and of great importance in giving free river navigation from the Willamette valley to the ocean.

The contractors not having proceeded with satisfactory diligence, at the end of a year the work was taken out of their hands and carried forward by Colonel Smith with great rapidity. Early completion was of vital importance to his company, as upon that depended a very large state subsidy which would have lapsed had the works not been completed at a certain fixed date, then drawing very near. The Colonel accomplished the desired end in time, and not only secured the large subsidy for his company, but turned over a work of which the excellence of design and thoroughness of execution marked its engineer as a man of notable skill and ability.

During the year 1873 but little engineering work was in progress in the Northwest, and Colonel Smith spent a good portion of the time superintending the execution of large land survey contracts awarded by the United States Surveyor General for Washington Territory. In December of that year he was called again to the service of the Northern Pacific Railroad Company, and placed in charge of the survey of the new terminal in the city of Tacoma, the location for which had been determined upon a few months before. In the latter part of 1874 he made an examination of the Fraser River in British Columbia, from Soda Creek to Lytton, reporting upon the feasibility of rendering the same navigable by the removal of gravel bars and rocky barriers. In February, 1875, he visited Peru at the invitation of Colonel Edward A. Flint, who hoped to secure for him a responsible position in connection with one of the trans-Andean railways then building.

Upon his arrival finding the country again in the throes of civil war, and all railway construction interrupted, he returned at once to California, and, entering the service of the Southern Pacific Railroad Company, was detailed to make surveys for that road in Arizona.

A year later, in association with Colonel George H. Mendell of the Corps of Engineers, U. S. A., he made an exhaustive study and report upon the water supply for the city of San Francisco. As Colonel Mendell's chief assistant he had charge of the extensive surveys which were made, including all the available sources of supply.

From April, 1876, to April, 1878, Colonel Smith was one of the Board of Railroad Commissioners for the State of California, the other commissioners being Mr. John T. Doyle and General George Stoneman. In May, 1878, he was appointed chief engineer of the Sacramento River Drainage District Commission which had under consideration a

project for a drainage canal to carry off flood waters along the west side of the valley opposite Sacramento, from Knight's Landing to Suisun Bay, a distance of 46 miles.

The issuance of bonds to a large amount for this undertaking depended upon the favorable report of the chief engineer. The surveys and examinations showing the project to be impracticable, the report of the engineer was decidedly adverse, and the scheme was abandoned.

From this time until the spring of 1880, Colonel Smith was chief engineer for the Board of State Harbor Commissioners of California, in which capacity he designed the sea wall for the water front of the city of San Francisco, and constructed upwards of a mile of it, together with its appurtenant wharves.

In April, 1880, he was again called to the service of the Northern Pacific Railroad Company, then about to undertake extended surveys of the Cascade Range, north of the Columbia in Washington, for the purpose of deciding upon the location of its line to Puget Sound, and was placed in full charge of the Cascade Mountain surveys. This work he prosecuted with great vigor, employing a large corps summer and winter, and before the end of the next year, 1881, the several routes across the mountains had been thoroughly examined. The route finally adopted, *via* Stampede Pass, was one of the new lines surveyed and mapped under his direction.

In September, 1881, he was appointed to the position of chief engineer of the Oregon Pacific Railroad Company, then engaged in constructing a line eastward from Yaquina Bay, Ore. He remained with this company two years, completing the line as far as Corvallis, about 60 miles, and then resigned and returned to Tacoma, Wash., where he made an examination and report upon the water supply for that city. During the years 1883 to 1885, he was chief engineer for the Tacoma Light and Water Company, designing and constructing the gas and water plants for Tacoma at an expense of nearly half a million dollars, and superintending the works for some months after completion. During this period he also made surveys and designed a system of improvements for the water front of Tacoma Harbor, for the Tacoma Land Company.

For many years the city of Portland, Ore., was furnished with water by a private corporation which pumped its supply from the Willamette River. The quality of the water not being satisfactory, the State legislature authorized the city to construct works of its own and placed the entire control of the water system in the hands of a water committee composed of well-known and substantial citizens. Early in the year 1886 this committee called Colonel Smith to its aid and placed in his hands the work of determining the future water supply for the city. After exhaustive surveys he reported in favor of a gravity supply from Bull Run River at a point in the foot hills of the

Cascade Range about 30 miles east of the city. The cost of bringing in as large a supply as desired being greater than expected, the construction of the proposed system was not at that time deemed expedient, and the existing system was purchased and Colonel Smith placed in charge as engineer and superintendent, which position he continued to hold until his death. Plans and specifications for the new gravity supply were prepared, and legislative authority having been secured for the issuance of bonds to obtain funds to carry them out, construction of the new system was begun in March, 1893, and completed January 1st, 1895, at an outlay of nearly $3 000 000.

This, his *magnum opus*, was the last of a long series of beneficent works he had constructed for the comfort, health and safety of mankind, and he was, happily, permitted to live to see it completed and in successful operation for two years before his death.

For several years his leisure hours were spent in the preparation of a treatise on the "Theory of Deflections and of Latitudes and Departures, with Special Application to Curvilinear Surveys and Alignments of Railway Tracks," which he published, and only a few months before his death he prepared a paper on the "Flow of Water in Wrought and Cast-Iron Pipes from 28 to 42 Ins. Diameter," for publication in the *Transactions* of this Society.*

He became a Member of the American Society of Civil Engineers on October 1st, 1873.

The foregoing is but a brief epitome of some of the occupations of a long and active life. Colonel Smith's reputation as an engineer of ability and integrity became established early, and his services were continually in demand. That all of the many positions of responsibility which he occupied were faithfully and acceptably filled none can dispute, as many monuments of his versatile genius amply testify. Those who came to know him intimately found a man in whom they could trust, always desirous of dealing justly with all men, and of doing that which was right for the sake of right and because it was in accord with the Divine command. Of commanding presence, he won the love and esteem of a large circle of friends and left an impress for good upon all with whom he came in contact. Although of a domestic disposition, the subject of our sketch never married.

The following, from the pen of one who was associated with Colonel Smith at various times, will meet with a sympathetic response in the hearts of all those who ever knew him.

"During the various periods when I was associated with Colonel Smith I had the opportunity of seeing him under many and varied circumstances. I can truly say that there was nothing in my whole

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* See Vol. xxxvi, p. 197.

acquaintance with him but what tended to increase my admiration and respect for the man. He was one of the few engineers whom I have ever been associated with who combined a thorough theoretical knowledge of mathematical principles with a practical grasp of the best methods for the solution of the various problems that were being constantly presented to him in the conduct of his work.

"The Colonel was not only a fine mathematician, but his acquaintance with, and pleasure in, the best classes of literature made him always a most charming and instructive companion. Reading seemed to be the kind of rest and relaxation he most enjoyed.

"There is one trait which characterized the Colonel to a marked degree, and that is his absolute integrity and incorruptibility. Another trait of his character was his thorough self-forgetting unselfishness. He was not only a devoted son and brother, but in his intercourse with the men in his employ he was always thinking of their comfort and welfare rather than his own. Certainly, in all my experience I do not know of another man who could equal the Colonel in his rare combination of strength and purity and gentleness of character. There is one character in fiction of whom the Colonel very often reminded me. I refer to Thackeray's character of Colonel Newcome.

"I shall always feel that it has been one of the privileges of my life to have known as intimately as I did a man of the character of Colonel Smith."

EDWARD SOUTHWICK PHILBRICK, M. Am. Soc. C. E.*

Died February 13th, 1889.

Edward Southwick Philbrick was born at Boston, Mass., November 20th, 1827, and was always identified with that city, although his residence was in Brookline for most of his life. His education was received in the local public schools and at Harvard College, where, however, he did not follow the regular course and never graduated. About twenty-five years later, however, the college granted him the degree which he had been prevented from obtaining in the regular manner.

Railroad engineering in New York and Vermont engaged his attention for a few years, but becoming interested in structural engineering, he relinquished his position to spend a year and a half abroad, part of the time studying at Paris, but most of the time in travel. Returning in 1855, he was for some time assistant superintendent and engineer of the Boston and Worcester Railroad.

Mr. Philbrick inherited strong anti-slavery convictions from his father, and after the outbreak of the Civil War was active in the work of the Sanitary Commission. When Port Royal was taken and great numbers of negroes entered the Union lines, Mr. Philbrick was among

* Memoir prepared from information furnished by George F. Swain, M. Am. Soc. C. E., and papers on file at the House of the Society.

the volunteers who went to that place to assist in educating the ex-slaves. There he remained until the close of the war, actively engaged in the work undertaken by the Freedmen's Societies which was of such aid during those trying times.

When the war was over he returned to Boston and became consulting engineer of the Boston and Albany Railroad, a position he held for a number of years. He had charge of the design and construction of many iron bridges on this road, of the large Union Station at Worcester, and of grain elevators in Boston. His observations and studies in Europe, where he had made a careful investigation of the methods of bridge construction, led him to become a strong advocate of riveted connections, and such details were employed exclusively on the bridges of the Boston and Albany road which were built under his direction. His practice with this company gradually led to his being consulted by other railway corporations, and he was recognized as an expert in matters pertaining to bridge work. Among his engagements was one by the State of Massachusetts as consulting engineer on the Hoosac Tunnel, and another as engineer of the improvement of the South Boston Flats.

Sanitary engineering was a favorite study with Mr. Philbrick. His architectural experience gave him an insight into the principles of plumbing and house drainage, and his knowledge of matters pertaining to sewerage and water supply led to frequent engagements by town and city authorities. He was among the earliest American engineers to insist on the importance of good plumbing and to urge the adoption of scientific methods in designing and carrying out such work. For a number of years he was a member of the Board of Selectmen and the Water Board of Brookline, and rendered particularly valuable service to the town in connection with the system of water-works built during this time.

Technical education had a strong advocate in Mr. Philbrick, and for many years he was a member of the corporation of the Massachusetts Institute of Technology, in which school he was accustomed to deliver a number of lectures annually.

Mr. Philbrick was elected a Member of the American Society of Civil Engineers on September 6th, 1874, and contributed two papers to *Transactions*. The first was published in Volume VII, and is entitled "The Improvement of the South Boston Flats;" the second was published in Volume XVII, and is entitled "Inspection and Maintenance of Railway Structures." He also took part in the discussion of several papers.

During the latter part of his life he was engaged in several business enterprises, and found little time for engineering work, although he continued to lecture before the students of the Massachusetts Institute of Technology.

For many years previous to his death he was a frequent contributor to the *Engineering Record*, and some of his articles in that paper were published in a book bearing the title "American Sanitary Engineering." A memoir of him in that journal closes as follows:

"Those who knew him but slightly may have been somewhat repelled by a certain brusqueness of manner, which at first seemed to imply some want of consideration for the feelings of others; but only those who knew him well can fully appreciated the kindly heart, the depth and tenderness of friendship, and the philanthropic spirit—manifested in many ways—which lay beneath the surface. Only such will fully realize their loss."

ISAIAH WILLIAM PENN LEWIS, M. Am. Soc. C. E.*

Died October 18th, 1856.

Isaiah William Penn Lewis was born in Charlestown (now Boston), Mass., July 15th, 1808. He was the son of Captain Isaiah Lewis and Harriet Ann Townsend Lewis, née Cox. He received his education in Boston, but owing to his father's death during his own boyhood he did not attempt to pursue professional life. He followed the sea for several years, which had been his father's occupation, and was in command of vessels trading to the East, to the Gulf of Mexico and elsewhere. Before he was thirty years of age he gave up maritime life and studied civil engineering in Boston and commenced business for himself in that city about 1840. In 1843-44 he made a visit to France and there made himself thoroughly familiar with the Fresnel system of lighthouse illumination, and on his return to this country undertook to secure its adoption by the United States Government, in which object, after long and arduous effort, he was finally successful.

From 1845 until the time of his death in 1856, he was almost constantly in government employment, engaged in visiting and reporting on the various lighthouses along our coast and in introducing the new system gradually. He superintended the construction of the lighthouse at Sand Key, Key West, Fla.; somewhat later, that at Galveston, Tex., and probably others. In connection with this employment he made several visits to England and the Continent, making extended examinations of lighthouse construction and operation, especially in the former country, and was in communication with various prominent scientific men, particularly with James Nasmyth, the eminent engineer and inventor.

Mr. Lewis married Miss Ellen Augusta Doane, in Boston, October 29th, 1840. Notwithstanding his extended absence, he retained his

* Memoir prepared by F. W. D. Holbrook, M. Am. Soc. C. E., and Joseph Willard, Esq.

citizenship in that place until his death, October 18th, 1856. He left no children.

Mr. Lewis's aptitude for mechanical construction may be fairly said to be hereditary. His grandfather, Lemuel Cox, was probably the most skilful bridge-builder of his day. He constructed, in 1786, the deep water bridge connecting Boston and Charlestown, after it had been repeatedly pronounced impracticable, owing to the rapidity, as well as the depth, of the tidewater, and subsequently built bridges at Malden and Salem, Mass. The Charlestown bridge was the first to connect Boston with surrounding main land. His success in these works led to his being invited to Ireland in 1789 to erect the bridge over the Foyle at Londonderry, which he completed in less than the contracted time, a remarkable compliment to his skill, coming as it did from the mother country to an American, and so soon after the Revolution. He was then employed to construct bridges at Wexford, Waterford, Ross Craig and elsewhere, and was engaged in these various enterprises nearly ten years before he returned to America.

Personally, Mr. Lewis was a man of very attractive manner, with exquisite taste and great skill in drawing, painting in water-colors, and music, and he made a wide circle of friends.

Mr. Lewis was elected a Member of the American Society of Civil Engineers on January 5th, 1853.

THEODORE DEHONE JUDAH, M. Am. Soc. C. E.*

Died November 2d, 1863.

Theodore Dehone Judah, to whom the first transcontinental railway in this country owes in a large measure its incorporation and early success, came from a family which settled at Westport, Conn., in the early days of the colony. His father was an Episcopal clergyman, and it was while he was rector of St. John's Church in Bridgeport, Conn., that the subject of this memoir was born, the date being March 4th, 1828. Soon afterward the family moved to Troy, N. Y., where the father was called to be the rector of St. John's Church, and the son received his early education in that city, studying at the Rensselaer Polytechnic Institute at one time. The father died before the son's studies were completed, however, and the family moved to New York City.

* Memoir prepared from information furnished by Mrs. R. A. Pierce, C. P. Huntington, F. Am. Soc. C. E., and from a lecture entitled, "Theodore D. Judah, the Engineer of the Central Pacific Railroad," delivered at Stanford University by Mr. Theodore H. Hittell.

By this time the young man was convinced that his talents destined him for the profession of engineering, and he soon joined the staff of S. W. Hall, then engineer of the Troy and Schenectady Railroad Company, and began his railroad career. Afterward he served under James Laurie, first President of this Society, and was engaged on the New Haven, Hartford and Springfield Railway and the Connecticut River Railroad. Another work of his in New England, which he referred to with pride, was the construction of a railroad bridge at Vergennes in Vermont. Subsequently he was a resident engineer on the Erie Canal, located at Jordan and Seneca Falls, and afterward was engineer of the railroad down the gorge of the Niagara River to Lewiston, a work which was considered a remarkable feat in those days, and resulted in his engagement as engineer of the first California railroad. He was employed on the construction of the Buffalo and New York Railroad, then pushing across the state to connect with the Erie line, when he received a telegram from Governor Seymour, who was acquainted with the Niagara line and the difficulties presented by its construction, to go to New York at once. There he met Colonel Charles L. Wilson, who was enthusiastic over the proposed railroad between Sacramento and Folsom, and immediately accepted the position of chief engineer of the enterprise. In a short time he and his wife were on their way to the Pacific Coast, and from then until his untimely death, his work assumes a character of great commercial importance. In a brief biography of her husband, Mrs. Judah states, "that everything he did from the time he went to California to the day of his death was for the great continental Pacific railway. It was the burden of his thought day and night and largely of his conversation."

It was as the chief engineer of the Central Pacific Railroad that Judah achieved his greatest reputation, not only as an engineer, but also as a promoter, using the word in its best sense. He was identified with California railroading from its beginning. The State Legislature passed a general law for the organization of railroad companies in 1850, and after it was amended several times, active preparation for work on a road was begun in 1853 by the Sacramento Valley Railroad Company. The most important step taken was the engagement of Judah as the engineer of the enterprise, in the manner mentioned. Immediately after reaching California he selected a route from Sacramento to Folsom, a distance of 32 miles. Grading was commenced early in 1855, and tracklaying in the summer, as soon as rails arrived. The road was opened in February, 1856, but did not prove as profitable as was anticipated. It was purchased nine years later by the principal owners of the Central Pacific Railroad Company.

A large part of Judah's time during the next three years was spent in Washington endeavoring to procure the passage of a bill making grants of land in California for railroad purposes. Congress was not

disposed at that time to take any definite action on the subject of a transcontinental railroad, then attracting considerable attention on the Pacific coast, so a railroad convention was held at Sacramento in September, 1859, to consider the matter. Each county in California, Oregon, Washington and Arizona was requested to send as many delegates as it had members in the state or territorial legislatures. The attendance was large. Among the delegates certainly the best posted and probably the most efficient was Judah, who was present as a member from Sacramento. He had studied the engineering problems of a transcontinental road and was thoroughly convinced of the practicability of such a project. It was chiefly due to the fullness, clearness and satisfactory character of the information he furnished that the convention declared its decided preference among the routes mentioned for the central one advocated by him, and appointed him to act as its accredited agent in presenting its proceedings to the President, Cabinet and Congress, and in promoting favorable action on a Pacific railroad bill.

The Washington mission was unsuccessful, owing to the sectional jealousy so strong at that time. Mr. Judah wrote out a full report of his work, which he sent to the executive committee of the convention with many important documents. An unusual part of the report was a statement that although the expenses of his mission had cost him $2 500, the only bills he had to present were two small accounts for printing, amounting together to $40. In spite of the temporary failure of this congressional campaign, he returned to California with unabated confidence in the project and endeavored to arouse greater local support for a continuance of the agitation. His first attempt to raise funds was made in San Francisco, but in spite of the fact that some of the capitalists to whom he presented his plans recognized their importance, the local business field offered such inducements of large and immediate returns that they did not care to back an enterprise bound to require great expenditures before any profit could be realized. Undismayed by his failure at San Francisco, Judah went to Sacramento, where he was sure of the influence of General Lauren Upson, editor of the Sacramento *Union*.

Among his fellow townsmen of Sacramento were four merchants, Collis P. Huntington, F. Am. Soc. C. E., and Mark Hopkins, who were hardware dealers; Charles Crocker, who was in the dry goods business, and Leland Stanford, who dealt in provisions and groceries. The first two had been in California since 1849; none of them was rich. These four men with Judah formed a quintette in which the deficiencies of any one member were remedied by the characteristics of the others. It was through their assistance and under the personal direction of Judah that the different routes over the Sierra Nevada Mountains were examined and compared.

The Central Pacific Railroad Company was organized on June 28th, 1861, under the laws of California, with a capital stock of $8 500 000 in $100 shares. C. P. Huntington, Leland Stanford, Mark Hopkins and Charles Crocker made liberal subscriptions to the stock, and a number of other citizens of Sacramento subscribed for smaller amounts. Judah organized his engineering parties again and crossed the mountains more than twenty times before making his final location. He confined his attention chiefly to three routes; the first through El Dorado County by way of Georgetown, the second through Illinoistown and Dutch Flat, and the third by the way of Nevada and Henness Pass. The Dutch Flat route proved the most practicable, as by it he could attain the summit at Donner Pass with lighter grades, at less distance, and with fewer obstacles than by any other line.

The problem presented was to ascend 7 000 ft., the height of Donner Pass, in a distance of not much more than 70 miles. After careful examination a long and unbroken spur of the Sierra Nevadas was found extending southwesterly from Donner Pass to the Sacramento Valley. By keeping on or near the ridge of this spur, the summit could be attained with a maximum grade not exceeding 105 ft. to the mile along a route crossing but one stream, and that a small one. On the other hand, the eastern slope of the Sierras could be descended as far as the Truckee River by means of two ravines south of Lake Donner, with a maximum grade of 140 ft. per mile. Judah's route followed the Truckee from a point near the outlet of Lake Donner, and about 14 miles north of Lake Tahoe, through the eastern ridge and Washoe Mountains to Big Bend in the Humboldt Desert, giving a grade not exceeding 40 ft. to the mile and entirely avoiding the second or eastern ridge of mountains. The distance from Sacramento to the Truckee was 123 miles by this route, and 145 miles to the State line. Judah estimated that eighteen tunnels would be necessary, and that the road could be kept free from snow throughout the year. The probable cost of the road was given as about $88 500 per mile for the entire 145 miles to the State boundary.

As soon as his report was made he was sent to Washington to procure aid for the construction of the road. He became acquainted with members of the committees on the Pacific Railroad in both branches of Congress and was appointed Secretary of both, with the privilege of the floor in both Senate and House. Although the opposition previously offered by southern Congressmen was wanting in this session by reason of the civil war, there were many obstacles to be overcome and much tactful manœuvering and compromise necessary before the desired legislation was obtained on July 1st, 1862. The act contained references to three companies. It incorporated the Union Pacific Railroad Company for constructing a part of the transcontinental route, provided for the construction of another part by the Leaven-

worth, Pawnee and Western Railroad Company of Kansas, and gave to the Central Pacific Railroad Company the recognition and privileges it had been struggling so hard to obtain. It was provided that the company might construct a railroad and telegraph line from the Pacific Coast, at or near San Francisco, or the navigable waters of the Sacramento River, to the eastern boundary of California. Right of way for 200 ft. on each side of the road was granted, and all ground needed for buildings and five alternate sections of public land, per mile, on each side of the line, or all the odd sections within the limits of 10 miles on each side which had not been sold, reserved or otherwise disposed of, except mineral lands. In consideration of the mountainous character of the country for 150 miles west from the eastern base of the Rocky Mountains, and for 150 miles east from the western base of the Sierra Nevada Mountains, the Secretary of the Treasury was instructed to issue to the company constructing these sections bonds to the amount of $48 000 per mile; the bonds to be issued and the lands granted set apart on the completion of every 20 miles of these portions of the road. The amount of bonds to be issued for the intermediate country between the Sierra Nevada and the Rocky Mountains was fixed at $32 000 per mile, and $16 000 for the remaining sections. The company had to build 50 miles in the first two years and 50 miles each additional year, half the amount of construction required of the Union Pacific Company.

Judah lost no time in filing in the office of the Secretary of the Interior the necessary maps and papers relating to the route of the Central Pacific Railroad, thereby securing the withdrawal from sale of land along the line. He made arrangements in New York for rails and other equipment for the first 50 miles of road, and late in July sailed for San Francisco, carrying with him a testimonial from a number of senators and representatives as to the value and effectiveness of his work.

The first shovelful of earth taken on the work of construction was moved at Sacramento by Leland Stanford on January 8th, 1863, the day following his inauguration as Governor of California. In spite of the national assistance granted during the preceding summer, work progressed slowly and capital was enlisted with difficulty. By this time the leading men in the enterprise had found the work best suited for each. Huntington became the eastern financial manager, and Stanford the western, Crocker devoted himself to superintending the construction, Hopkins looked after the supplies, and Judah superintended the engineering work. Six months later, Judah filed a report estimating the cost of the first 50 miles of the road at nearly $3 250 000; at this time, the bridge over the American River was nearly completed and about 18 miles graded. Six thousand tons of rails had been purchased, six locomotives and about fifty cars.

In October of the same year, he sailed from San Francisco to urge further legislation by Congress for the transcontinental railroads, and to affect certain changes in the company. The latter are best indicated by the following quotation from Mrs. Judah's memoir of the husband.

"Mr. Judah saw he must place himself differently, and he went to work to accomplish it. He had secured the right and had the power to buy out the men opposed to him and the true interests of the Pacific Railroad at that time. Everything was arranged for a meeting in New York City on his arrival. Gentlemen from New York and Boston were ready to take their places. They could not see him. Two of the gentlemen came to see me in Greenfield, thinking I might be able to give them points for their interest."

He was attacked by fever on the journey, and died on November 2d, 1863, at New York. His work was carried on by the parties before mentioned, who had furnished financial backing to the enterprise, until it has expanded into one of the most powerful railway systems of the world. Judah was, in a measure, its founder and most influential advocate, and it was largely through his manifold talents, apart from engineering, that a transcontinental railway was recognized as of national importance by Congress.

Mr. Judah was elected a Member of the American Society of Civil Engineers on May 4th, 1853.

Vol. XXIII. SEPTEMBER, 1897. No. 7.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publication.

CONTENTS.

SOCIETY AFFAIRS.

PAPERS.

ILLUSTRATIONS.

The price of publications is as follows: Proceedings, $6 per annum; Transactions, $10 per annum. Postage will be added when they are sent to foreign countries.

American Society of Civil Engineers.

OFFICERS FOR 1897.

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Term expires January, 1898:
WILLIAM R. HUTTON,
P. ALEXANDER PETERSON.

Term expires January, 1899:
GEORGE H. MENDELL,
JOHN F. WALLACE.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOHN THOMSON.

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Term expires January, 1898:
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CHARLES SOOYSMITH,
GEORGE H. BENZENBERG,
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Special Committees.

ON UNIFORM STANDARD TIME:—Sandford Fleming, Charles Paine, Theodore N. Ely J. M. Toucey, T. Egleston.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf, Thomas Rodd, A. E. Hunt.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—127 EAST TWENTY-THIRD STREET, NEW YORK.

Vol. XXIII. SEPTEMBER, 1897. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

September 1st, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 55 members and 10 visitors.

The minutes of the meetings of June 2d and 30th, and July 1st, 1897, were approved as printed in *Proceedings* for August, 1897.

The Secretary announced that the Board of Direction had decided to hold the next annual convention at Detroit, Mich., during the last week of July, 1898.

The Secretary read a paper by J. F. Wallace, M. Am. Soc. C. E., entitled "The Lake Front Improvements of the Illinois Central Railroad in Chicago," which was discussed by Messrs. C. T. Purdy, L. M. Haupt, and Edward P. North.

At the close of the discussion on Mr. Wallace's paper, there was a discussion on the effect of exceptionally heavy rainfall on earthworks by Messrs. L. M. Haupt, James Owen, E. J. Chibas, F. P. Davis, F. P. Lant, Boyd Ehle and Samuel Whinery.*

The Secretary presented a letter from J. A. L. Waddell, M. Am. Soc. C. E., suggesting the appointment of a committee of the Society to test all kinds of paint for structural steel. A motion to refer the matter to the Board of Direction received but 8 affirmative votes, and was declared lost in accordance with Article VI, Section 13, of the Constitution.

Ballots were canvassed and the following candidates declared elected:

As Members.

John Moyer Farley, White Plains, N. Y.
James Wesson Kittrell, Rome, N. Y.
Hermann Laub, Pittsburg, Pa.
John Alexander McNicol, Providence, R. I.
Ivar Ludwig Sjöström, Lawrence, Mass.
William Francis Tye, Trail, B. C., Canada.

As Associate Members.

William Davis Barber, Chicago, Ill.
Henry James Eder, Palmira, Cauca, Republic of Colombia.
Charles Edward Gudewill, Montreal, P. Q., Canada.
George MacLeod, Louisville, Ky.
Daniel Ulrich, New York City.

The Secretary announced the election by the Board of Direction on August 31st, 1897, of the following candidates:

As Associates.

James Archibald Huston, Toledo, Ohio.
Frederick Eugene Turneaure, Madison, Wis.

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* This informal discussion will be published in *Proceedings* for October, 1897.

As Juniors.

James George Beach, New York City.
John A. Clark, Jr., New York City.
John Lyle Harrington, Philadelphia, Pa.
Theodore Horton, Boston, Mass.
Charles Greene Waitt, Malden, Mass.

The Secretary announced the deaths of the following members:

Charles Benjamin Brush, elected Associate, September 6th, 1871; Member, September 5th, 1877; Director, 1888 to 1891 inclusive; Vice-President, 1892 and 1893; died June 3d, 1897.

Mirtiliano Sicard, elected Member, January 4th, 1882; died March 17th, 1896.

Adjourned.

September 15th, 1897.—The meeting was called to order at 20.20 o'clock, W. R. Hutton, Vice-President, in the chair; Charles Warren Hunt, Secretary, and present, also, 51 members and 10 visitors.

A paper by J. L. Van Ornum, Assoc. M. Am. Soc. C. E., entitled, "Theory and Practice of Special Assessments," was presented by the Secretary, and discussed by Messrs. Owen, Tillson, Davis and North.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

August 31st, 1897.—Seven members present.

The report of the Committee appointed to recommend the place and time for holding the Annual Convention of 1898 was received, and, in accordance with its recommendations, Detroit was selected as the place for holding the Convention of 1898, and the last week in July was selected as the time.

Applications were considered and other routine business transacted.

Two candidates were elected as Associates and five as Juniors.

Adjourned.

ANNOUNCEMENTS.

MEETINGS.

Wednesday, October 6th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by J. P. Frizell, M. Am. Soc. C. E., entitled "Pressure Resulting from Changes of Velocity of Water in Pipes," will be presented. It was printed in the August number of *Proceedings*.

Wednesday, October 20th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by O. E. Selby, Jun. Am. Soc. C. E., entitled "Painting the Louisville and Jeffersonville Bridge," will be presented. It is printed in this number of *Proceedings*.

Wednesday, November 3d, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Corydon T. Purdy, M. Am. Soc. C. E., entitled "Can Buildings be Made Fire-Proof?" will be presented. It is printed in this number of *Proceedings*.

DISCUSSIONS.

Discussion on the paper by J. F. Wallace, M. Am. Soc. C. E., entitled "The Lake Front Improvements of the Illinois Central Railroad in Chicago," which was presented at the meeting of September 1st, 1897, will be closed October 15th, 1897.

Discussion on the paper by J. L. Van Ornum, Assoc. M. Am. Soc. C. E., entitled "Theory and Practice of Special Assessments," which was presented at the meeting of September 15th, 1897, will be closed November 1st, 1897.

LIST OF MEMBERS.

ADDITIONS.

MEMBER.

			Date of Membership.
FARLEY, JOHN MOYER	White Plains, N. Y.	J.	Dec. 5, 1888
		Assoc. M.	July 1, 1891
		M.	Sept. 1, 1897

ASSOCIATE MEMBERS.

AYLETT, PHILIP	City Island, New York City	June 3, 1896
FERGUSON, HARDY SMITH	Berlin, N. H.	Mar. 3, 1897
GUDEWILL, CHARLES EDWARD	Vice-Pres. Montreal Pipe Foundry Co., P.O. Box 739, Montreal, Canada.	Sept. 1, 1897

		Date of Membership.
SMITH, LEONARD SEWALL	Asst. Professor, Topographic and Geodetic Engineering, University of Wisconsin, Madison, Wis.	June 2, 1897
THROOP, AUGUSTUS THOMPSON	Asst. Engr. Cataract Const. Co., Niagara Falls, N. Y.	Mar. 3, 1897
ULRICH, DANIEL	353 Lenox Ave., New York City	Sept. 1, 1897

JUNIORS.

MCCAFFERY, RICHARD STANISLAUS	316 East 124th St., New York City	May 4, 1897
WAITT, CHARLES GREENE	Waitt's Block, Malden, Mass.	Aug. 31, 1897

CHANGES AND CORRECTIONS.

MEMBERS.

ADGATE, GEORGE....................Cornwall, Ontario, Canada.
BEAHAN, WILLARD....................Wellington, King Co., Wash.
CARTER, OBERLIN MONTGOMERY........Care of Nicaraguan Canal Comm., Army Bldg., New York City.
CHEEVER, ALBERT SAFFORD............Secy. and Treas. Grant Ball Co., 451 Bolton Ave., Cleveland, Ohio.
CRAIG, CHAMBERS MCKIBBIN..........Savannah, Ga.
ELLIOTT, CHARLES GLEASON...........Marietta, Ohio.
FULLER, WILLIAM BARNARD...........57 Lumber District, Albany, N. Y.
GARFIAS, IGNACIO....................Dir. Mex. Hydrographic Comm., Secy. of Comm. and Pub. Wks., 8 Calle de Chavarria, Mexico, D. F.
GAY, MARTIN.........................163 West 121st St., New York City.
GERBER, EMIL........................Engr. Lassig Bridge & Iron Works, 348 Belden Ave., Chicago, Ill.
GIBBS, GEORGE.......................Baldwin Locomotive Works, Philadelphia, Pa.
HAINES, HENRY STEVENS..............Care of Arthur S. Haines, 11½ E. Alabama St., Atlanta, Ga.
HARRIS, WILLIAM POND...............Supt. Plant System of Rys., Montgomery, Ala.
HILGARD, KARL EMIL.................18 Steinwiesgasse, Zürich, Switzerland.
JEWETT, WILLIAM CORNELL............541 Ridgeway Ave., Avondale, Cincinnati, Ohio.
LAWLOR, FRANCIS DENIS HUBERT......Cardinal, Grenville Co., Ont., Canada.
MELCHER, FRANK OTIS................Chf. Engr. Fitchburg R. R. Co., Fitchburg, Mass.

MORLEY, FRED	Prof. of Civil Engineering, Purdue University, La Fayette, Ind.
PRENDERGAST, FRANCIS ENSOR	Redlands, Cal.
RAYMOND, CHARLES WARD	Supt. Grand Victory Gold Mining Co., Placerville, Cal.
TAYLOR, LUCIAN ARNOLD	73 Tremont St., Room 609, Boston, Mass.
VAN DER HOEK, JACOBUS	Div. Engr. Lehigh Val. R. R., 127 Northland Ave., Buffalo, N. Y.

ASSOCIATE MEMBERS.

ADAMS, JR., EDWIN GRIGGS	Dir. School of Civil Engineering, Imperial University, Tientsin, China.
BROWNELL, ERNEST H.	General Delivery, Station H, Brooklyn, N. Y.
CHIBAS, EDUARDO JUSTO	Care of Am. Soc. C. E., 127 East 23d St., New York City.
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ADDITIONS TO

LIBRARY AND MUSEUM.

From Alabama Industrial and Scientific Society, University, Ala.:
Proceedings, Vol. VII, Part 1, 1897.

From Board of Public Works, Duluth, Minn.:
Tenth Annual Report for the year ending February 28th, 1897.

From L. de Chasseloup-Laubat, Paris, France:
Les Chaudières Marines.

From Frank N. Cilley, Onset, Mass.:
Some Fundamental Propositions relating to the Design of Frameworks.

From Joao Severo Cunha, Lisbon, Portugal:
Estudo sobre Abobadas.

From Institution of Mechanical Engineers, London, Eng.:
Proceedings, July, 1896.

From Iron and Steel Institute, London, Eng.:
Journal, Vol. LI.
List of Members, 1897.

From John Kennedy, Montreal, Can.:
Annual Report of the Harbour Commissioners of Montreal for the year 1896.

From Theodore A. Leisen, Wilmington, Del.;
Report of the Board of Park Commissioners of Wilmington, Del., for the years 1895 and 1896.

From William B. Mackensie, Moncton, Can.:
Painting Metal Bridges

From Minister of Agriculture and of Public Works, Brussels, Belgium:
Annales des Travaux Publics de Belgique, February, 1896, to June, 1897. Nine numbers.

From G. S. Morison, Chicago, Ill.:
Report of Board to Locate a Deep-Water Harbor at Port Los Angeles or at San Pedro, Cal.

From New England Cotton Manufacturers' Association, Boston, Mass.:
Transactions of Annual Meeting, April, 1897.

From Patent Office, London, Eng.:
Abridgments of Specifications of Patents for Inventions; Metals, Cutting and Working.

From Technical Highschool, Aix-la-Chapelle, Germany:
Programm für das Studien-Jahr 1897-98.

From Technical Highschool, Berlin, Germany:
Programm für das Studen-Jahr 1897-98.

From Technical Highschool, Hanover, Germany;
Programm für das Studien-Jahr 1897-98.

From John C. Trautwine, Jr., Philadelphia, Pa.:
Annual Reports of the Municipal Departments of the City of Philadelphia for the year ending December 31st, 1896.

From U. S. Coast and Geodetic Survey:
Table of Depths for Channels and Harbors, Coasts of the United States.

From U. S. Geological Survey:
List of Publications of the United States Geological Survey.

From U. S. War Department, Chief of Engineers:
Three Reports of the Surveys of Certain Rivers and Harbors.
Report of Board to Locate a Deep-Water Harbor at Port Los Angeles or at San Pedro, Cal., 1897.

From U. S. War Department, Ordnance Office:
Annual Report of the Chief of Ordnance for the fiscal year ended June 30th, 1896.

From H. D. Vought, Buffalo, N. Y.:
Proceedings of the Central Railway Club, January, March, April, September, October, 1893; September, 1894; March, 1896; January, May, 1897.

From George S. Webster, Philadelphia, Pa.:
Annual Report of the Bureau of Surveys of Philadelphia, Pa., for the year ending December 31st, 1896.

From H. D. Woods, Newton, Mass.:
Annual Report of the City Engineer of the City of Newton, Mass., for the year ending December 31st, 1896.

BOOK REVIEWS.

Sewer Flushing Diagrams. (From Actual Tests made principally upon Pipe Sewers.) Showing how far the Discharge from a Flush-Tank Will Give a Self-Cleansing Velocity. By S. H. Adams. New York, Spon & Chamberlain. Cardboard, 13½ x 10 ins. Three pages of diagrams.

The diagrams prepared by Mr. Adams show the effect of flushing sewers of various sizes and grades with different volumes of water. The diagrams are arranged with the abscissas representing the length of sewer, starting from the flush-tank, and the ordinates representing velocities of flow. To apply the information plotted on these sheets to any given case, the diagram for the sewer having conditions approaching nearest to those of the proposed case is selected. The length of sewer in which the velocity of flow is shown by the ordinates of the curve to be 2½ ft., or more may be taken as the length which will be flushed effectively by the discharge of the volume of water stated.

115 Experiments on the Carrying Capacity of Large, Riveted, Metal Conduits, up to Six Feet per Second of Velocity of Flow. By Clemens Herschel, Hydraulic Engineer, S. B. (Harvard, 1860); Past-Pres. Boston Soc. C. E., M. Am. Soc. C. E., M. Inst. C. E., Superintendent and Engineer of the East Jersey Water Co. of New Jersey. New York, John Wiley & Sons. Cloth, 6 x 9 ins., pp. 119, 14 plates.

Mr. Herschel states that of the 115 experiments discussed in this book, 84 are original and now published for the first time. These are mostly experiments on a class of conduits on which the results of no experiments have previously been printed so far as he knows. The heads of the chapters in the book are as follows: Introductory and Historical; Computation of a 48-In. Riveted Conduit between October, 1889, and December 22d, 1889; the Rochester Crime against Hydraulic Engineering; Experiments on Riveted Conduits, mostly made subsequent to the Rochester Exposure of 1890; Q and h; the coefficient c in $v = c\sqrt{rs}$; $v =$ tabulated $c \times \sqrt{rs}$; appendix.

The Materials of Construction. A Treatise for Engineers on the Strength of Engineering Materials. By J. B. Johnson, C. E. New York, John Wiley & Sons. Cloth, 6 x 9 ins., pp. 800, eleven plates and 637 cuts.

Professor Johnson has divided his treatise into four parts. The first, taking up 86 pages, contains an introductory chapter on the general nature of deformation and stress, followed by chapters on materials under tensile, compressive, shearing and cross-bending stresses and on resilience. Part second, of 215 pages, discusses the manufacture and general properties of the materials of construction, including cast and wrought iron, steel, copper, zinc, tin, aluminum, alloys, lime, cement, mortar, concrete, paving brick and timber. The third part covers 167 pages, and is given up to a description of testing machines and methods of testing materials, while the fourth part, embracing 254 pages, is a statement of the mechanical properties of the materials of construction as revealed by actual tests. Four appendices follow the main body of the book; the first is a brief sketch of the career of Professor Johann Bauschinger, whose portrait forms the frontispiece of the volume, the second a description of the latest methods of investigation of metals and building stones by means of the microscope, the third a translation of M. Baclé's comparison of American and foreign methods of testing, and the last a number of specifications for iron and steel. It is stated in the preface: "It has been no part of the author's aim to give working rules for using materials in structures of various kinds, or to propose original specifications to be used in the purchase of materials. He has tried to impart a knowledge of the properties of materials; on what these depend; the ordinary causes of variation and defects, and how these should be discovered; thus making the reader competent to draw his own specifications and to make his own rules."

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS:

PAINTING THE LOUISVILLE AND JEFFERSON-VILLE BRIDGE.

By O. E. SELBY, Jun. Am. Soc. C. E.

TO BE PRESENTED OCTOBER 20TH, 1897.

The Louisville and Jeffersonville Bridge across the Ohio River at Louisville was completed in May, 1895. Owing to a disagreement with the contractor as to the terms of the contract regarding painting, no painting had been done during erection, except on joints and parts inaccessible after erection. It was finally agreed in the settlement that the painting should be done by the company, and bids were received from several contractors for doing the work on a lump-sum basis. The most favorable bid received amounted to $7 500 for labor and equipment, the company to furnish the paint. It was thought by the chief engineer, Mr. Epes Randolph, that the work could be done by the company's force for less money, so men were employed, equipment was purchased and the work done under the direction of the author at

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a cost for labor, equipment and insurance of $4 928, and for paint of $3 769, making total cost $8 697. Careful record was kept of the cost of labor and materials for different parts of the work, and the purpose of this paper is to present an analysis of the results obtained and give such data on the cost of painting as were established and may be of value.

The work covered comprised the main river spans and viaduct approaches as follows:

Jeffersonville approach........	4 063 ft.	
Span No. 1....................	208 ft. 6 ins.	center to center.
Spans Nos. 2, 3 and 4, each.....	546 ft. 6 ins.	" "
Spans Nos. 5 and 6, "	338 ft. 0 in.	" "
Louisville approach...........	2 586 ft.;	

all single-track railroad bridge, except 1 000 ft. of the south end of the Jeffersonville approach, which is double-track, with a height of 50 ft. The average height of the Jeffersonville approach is 40 ft., and that of the Louisville approach 45 ft.

The part painted, and referred to in this paper, extends from Ninth Street in Jeffersonville to Franklin Street in Louisville, a distance of 9 194 ft. The total weight of iron covered was 12 795 000 lbs., including sidewalk railings. The finished length of the bridge is 10 273 ft. from abutment to abutment, the additional lengths of approaches having been built and painted under separate contract.

The Jeffersonville approach and span No. 1 were erected during the summer of 1890, and had been painted one coat in October, 1892, to preserve the iron during a suspension of work on the bridge. This part was gone over first, and spots which had begun to rust through were cleaned and painted one coat. After this had dried, one full coat was put on all over. All the remainder was new iron erected in 1893 and 1894, and received two full coats, except the inside of top chords and inclined end posts, which were painted one coat only. In defence of this last, the author's observation is that one coat on the inside of top chords will last in good condition longer than two coats on exposed parts. It is a part of the span absolutely protected from the weather and very difficult to get at and paint, and the omission of the second coat on nearly a mile of top chord and end posts in this case effected a very material saving in cost.

All the iron had a shop coat of linseed oil.

The work was begun June 3d and finished August 7th, 1895, thus

occupying a few days over two months, and was carried on without accident of any sort. The force ranged from thirty to sixty men and averaged about fifty men with foreman, assistant foreman and time-keeper. After July 1st, the timekeeper was employed partly on other work, and but half his time was charged to painting.

The men were mostly ordinary bridgemen, erectors and carpenters, and were paid usually $2 per day of ten hours. Some few inexperienced men at work on sidewalk railings and other parts not classed as hazardous were paid $1 25 and $1 50 per day.

After July 1st, there were infrequent trains on the bridge, but otherwise there was no necessity for keeping the track open for traffic, and this fact was, no doubt, of considerable influence in reducing the labor cost below what it would have been for a bridge under traffic.

The paint used was an oxide of iron paint selected by the chief engineer. One hundred and twenty barrels were bought, in two car-loads, and 104 used, the balance being sold. Four barrels at a time were carried on a push-cart and shoved along the track, as needed. One man was kept busy stirring up the paint, serving it out to the men, opening barrels, etc. The paint was used just as it came from the barrel, except for a little thinning occasionally with boiled linseed oil, of which one barrel was used, equivalent to about one-half gallon of oil per barrel of paint.

The equipment consisted of 8 painting stages; 20 stirrups, 18 tie-hooks and 16 hook chains for hanging the stages; 24 6-in. single blocks; 24 6-in. double blocks; 6 coils of ¾-in. manilla rope for falls; 1 coil of ½-in. manilla rope for hand lines, etc.; 1 standard railroad push-car; 19 dozen paint brushes; 4 dozen steel brushes; 13 dozen whisk brooms; 3 dozen steel scrapers; 4 dozen 1½-gall. black iron paint buckets; 1 dozen 2½-gall. black iron paint buckets; ½ dozen sheep skins.

The stages were home made, 6 ins. x 18 ins. x 35 ft., with sides of 2 x 6-in. poplar and 1-in. planks laid on the rungs. The tie-hooks, of 1-in. round iron, were used to suspend the stages from the long ties which projected to carry the sidewalks. The hook-chains were used to suspend the stages from the top chords of the trusses. Details of these chains, tie-hooks, stirrups and stages are shown in Fig. 1.

The amount of paint used was 5 612 galls., and the cost, charged to paint, was $3 769 12, equal to 67 cents per gallon. The price of the paint was 65 cents per gallon delivered at Louisville, and the addi-

tional 2 cents covers cost of drayage and handling, loss on paint sold, etc.

The total cost of the work is distributed as follows: Paint, $3 769 12; labor of painting and cleaning, $4 427 08; equipment, $300 84; accident insurance, $200; total, $8 697 04.

The item of equipment includes a credit of $170 91 for materials sold after the work was finished.

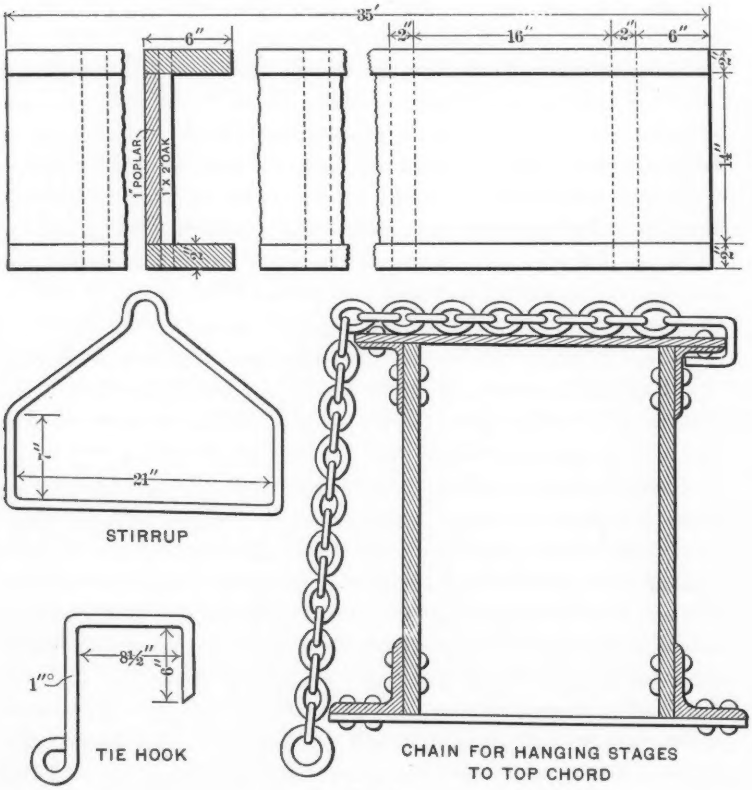

FIG. 1.

The table on page 442 shows the separate charges for labor and paint for each coat on the different parts of the work, the percentage of the whole which each coat represents, the labor cost per gallon of paint, and the labor cost, cost of paint and gallons of paint for each coat per 1 000 lbs. of iron and per lineal foot of structure.

In the distribution of cost, span No. 1, 208 ft. 6 ins. was included with the Jeffersonville approach, because they both received one coat only, and because this distribution equalized the general character of this approach with that of the Louisville approach, which contains one 200-ft. span.

No attempt was made to analyze the cost on the basis of surface covered, as this would have been an exceedingly tedious job and of little use. It is believed that the cost per lineal foot and per pound of iron covered will be of much more value in estimating on other work, and will be found nearly constant for the same class of work.

In making preliminary estimates for this work the author found very little in print on the cost of painting, and that little not in a form which made it available for a close estimate. This paper is presented in the hope that the discussion may bring out some further information on the subject from the note-books of engineers who have had charge of much similar work.

From a study of the table on page 442 the following facts seem to be established:

First.—The cost of the first coat in paint, labor and total is not far from six-tenths, and of the second coat, four-tenths, of the whole cost.

Second.—On the approaches, the labor cost per gallon of paint is much higher for the first coat than for the second, showing the influence of increased labor required in cleaning and scraping the iron. On the spans the labor cost per gallon is slightly greater for the second coat than for the first, showing that the cost of rigging and climbing to get at the work overbalances the labor of cleaning.

For approaches of this kind and for spans up to about 350 ft., it would seem to be on the safe side to estimate the labor cost at 75 cents per gallon of paint used, both coats. For spans in the neighborhood of 500 ft., this could be reduced to 66 cents.

Third.—The labor cost per 1 000 lbs. of iron is highest for the approaches and least for the long spans, and could be safely estimated at 55 cents per 1 000 lbs. for approaches, 41 cents for spans up to 350 ft., and 27 cents for spans of 500 ft., and over. The labor cost per 1 000 lbs. on the Jeffersonville approach for the one coat was intermediate between the cost of first coat and second coat on the Louisville approach, as it should be, as this was put on over an old first

Table Showing Distribution of Cost of Painting.

	Labor.					Paint.							Total.			
									Gallons.							
	Cost.	Per cent. of total.	Per 1 000 lbs.	Per lineal foot.	Per gallon.	Cost.	Per 1 000 lbs.	Per lineal foot.	Gallons.	Per cent. of total.	Per 1 000 lbs.	Per lineal foot.	Cost.	Per cent. of total.	Per 1 000 lbs.	Per lineal foot.
Jeffersonville Approach and Span No. 1, 4 271 ft. 6 ins., 3 525 000 lbs........	$899 26	......	cts. 25.5	cts. 21	cts. 81	$740 79	cts. 21.0	cts. 17	1 103	......	.31	.26	$1 640 05	......	cts. 46.5	cts. 38
Louisville Approach, 2 585 ft., 2 023 000 lbs. — First coat....	726 12	65	35.9	28	79	618 53	30.5	24	921	61	.45	.35	1 344 65	63	66.4	52
Second coat.	382 88	35	18.9	15	65	395 60	19.6	15	589	39	.29	.23	778 48	37	38.5	30
Total........	$1 109 00	100	54.8	43	73	$1 014 13	50.1	39	1 510	100	.74	.58	$2 123 13	100	104.9	82
Spans Nos. 5 and 6, 676 ft., 1 330 000 lbs.. — First coat....	312 90	58	23.5	46	72	291 51	21.9	43	434	59	.33	.64	604 41	58.5	45.4	89
Second coat.	229 35	42	17.2	34	76	201 49	15.2	30	300	41	.22	.44	430 84	41.5	32.4	64
Total........	$542 25	100	40.7	80	74	$493 00	37.1	73	734	100	.55	1.08	$1 035 25	100	77.8	153
Spans Nos. 2, 3 and 4, 1 639 ft., 6 ins., 5 535 000 lbs.......... — First coat....	880 20	59	15.9	54	65	914 73	16.5	56	1 362	60	.25	.83	1 794 93	59.5	32.4	110
Second coat.	606 28	41	10.9	37	67	606 47	11.0	37	903	40	.16	.55	1 212 75	40.5	21.9	74
Total........	$1 486 48	100	26.9	91	66	$1 521 20	27.5	93	2 265	100	.41	1.38	$3 007 68	100	54.3	184
Railings..............................	390 09	......	......	......	...	....	......	......	......	......	......	......	390 09			
	$4 427 08	......	......	......	...	$3 769 12	......	......	......	......	......	......	$8 196 20	......	......	......

coat requiring a considerable amount of cleaning, but still not so much as a first coat on rusty iron.

Fourth.—The labor cost per lineal foot of structure approximates 45 cents on single-track viaduct approach, 80 cents on 300-ft. spans, and 90 cents on 500-ft. spans.

Fifth.—The cost of paint can be taken as equal to the cost of labor without material error. This, of course, will vary with the kind of paint used and the price of linseed oil, etc., but may be taken as a good rule-of-thumb method. On the approaches and short spans the cost of paint was 91% of the cost of labor, and on the long spans 103 per cent.

This is, of course, but another view of the data given on the cost of labor per gallon of paint, and would seem to indicate that a given amount of rigging and climbing on the long spans allows a man to reach more iron and apply more paint than on the shorter spans and approaches. Spans Nos. 5 and 6 were erected in the latter part of 1893, while the long spans were erected more than a year later, so that the rustier condition of the shorter spans may account for their taking more paint.

Sixth.—The number of gallons of paint per 1 000 lbs. of iron decreases rapidly as the length of span increases, and may be taken at 0.75 gall. for approaches, 0.55 gall. for the shorter spans, and 0.4 gall. for the long spans.

Seventh.—The number of gallons per lineal foot increases rapidly with the length of span and may be estimated at 0.6 gall., 1.1 galls., and 1.4 galls., respectively, for the three classes of work.

Eighth.—The total cost may be taken at $1 05 per 1 000 lbs., or $0 82 per lineal foot, for single-track viaduct of an average height of about 45 ft. For spans of, say, 300 to 400 ft. the cost will be $0 78 per 1 000 lbs., or $1 55 per lineal foot, and for spans of 500 to 550 ft. $0 55 per 1 000 lbs., or $1 85 per lineal foot. For spans of intermediate lengths, the cost could probably be taken in proportion without serious error.

Ninth.—It is not observed that any of the items of unit cost vary as the first power of the span length or as the square of the span length, but usually as some intermediate power.

The labor cost of painting the 5 700 lin. ft. of sidewalk railings was $390 09, equal to $6 85 per 100 lin. ft. There are two sidewalks, one on each side of the track, each 5 ft. wide, and having a line of lattice railing 4 ft. high on the outside and a gas pipe railing next to the

track, consisting of two lines of $1\frac{1}{4}$-in. gas pipe. The amount of paint used on the railings was comparatively small, and was included in the amount used on the spans.

The cost of equipment, not deducting for material sold afterward, was $471 75, equal to about $10 per man employed. For a smaller gang doing the same work, the total cost of equipment would be less, but the cost per man would be higher, as a large part of this expense is for brushes, the number of which used depends on the amount of work done, rather than on the number of men employed. The best results were obtained from a flat brush costing $7 50 per dozen. These were good until worn down short, while a cheaper brush did not have the requisite stiffness and elasticity.

The painting of the Jeffersonville approach, the first coat in 1892, was done at a cost of about $2 300, making the total cost of painting the entire work 9 194 ft. long, with two coats, $11 000.

The results in this case seem to be a good argument for the use of oxide of iron paint. It was cheap in first cost, easily applied, and so far the indications are that it will prove exceedingly durable. The work at the present time after two years is apparently in as good condition as when finished, and examination shows no sign of rusting or beginning of failure. This good result is partly due to the good quality of the paint, and partly to the care used in cleaning the iron before applying the paint. It is exceedingly doubtful if as good results could have been obtained by contract work; in fact, the work on the approach extensions adjacent, done just previously by a reliable and honest contractor, with the same kind of paint, under inspection by the same man who was foreman on this work, already shows signs of rusting through in places. The secret of good results with an oxide of iron paint seems to be to get an honest paint and have it honestly applied. This same injunction applies, of course, to other paints, but not with equal force, and the author has no doubt that much of the bad odor into which oxide of iron paint seems to have fallen arises from using cheap paints adulterated on the ground with benzine, and applied on iron which has not been thoroughly cleaned.

The deductions made in the foregoing pages as to the covering power, etc., of the paint, and its cost, are, of course, based on the kind of paint used in this work, and would be modified somewhat in case red lead or other paint were substituted for it.

1897. SEPTEMBER. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS.

CAN BUILDINGS BE MADE FIRE-PROOF?

By CORYDON T. PURDY, M. Am. Soc. C. E.

TO BE PRESENTED NOVEMBER 3D, 1897.

One of the most destructive fires of this year occurred in Pittsburg on the morning of May 3d, the total loss being about $2 500 000. Three buildings, which were generally regarded as fire-proof structures, and were supposed to be constructed according to the most modern methods, were partially burned, and the contents of two of them were entirely destroyed. This circumstance has aroused an unusual interest among all classes of people in the construction of such buildings. Very much has been written by the technical press, both of the fire and of the lessons which the writers would draw from it. The loss in these particular buildings has also tended strongly to condemn all buildings of their class in the public mind, so that even among men who know most about building construction the question whether buildings can really be built fire-proof or not is pertinent.

The purpose of this paper is to relate in brief the incident of the fire, to describe the important characteristics of the construction, and

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to point out the lessons which are taught. Much has already been well said, while some things have been written that are not so, and some important points are not yet brought out. It is hoped that this paper and the discussion of it by the Society will correct any wrong impressions of the fire, and bring out clearly every point which can be of advantage to engineers or architects.

The author has endeavored to avail himself of every opportunity to obtain definite and reliable information as to the construction of the buildings and the circumstances of the fire, making for the purpose a personal examination of the ruins.

It is one of a very few fires which have burned fiercely in buildings of modern construction, and, while it is not as good a test of some conditions as other fires have been, notably so, the burning of the Athletic Club Building in Chicago, it is of greater interest, because it concerns different methods of construction and several forms of fire-proofing materials. Practically everything that was combustible in the Horne Store Building was burned, and the steel frame on one side was badly wrecked. The contents of the Horne Office Building were also consumed, as was most of the woodwork in the construction of the building. The fire in the Methodist Building was mostly confined to the three upper floors, where the contents and much of the wood finish were burned. These are the so-called fireproof buildings. The Jenkins Building, where the fire first started, and several smaller ones were entirely consumed. The lessons of the fire are, therefore, confined to the two Horne Buildings and the Methodist Building.

The location of these buildings and their relations to each other are shown on the map of the fire district, Fig. 1.

The Horne Store Building was built in 1893. It is six stories high, without partitions, and with an opening in the center 22 ft. wide and 50 ft. long, extending from the first floor to the top story, surrounded on each floor by an iron balustrade. There were also four passenger elevators on one side of the building, with a grand staircase between them. The opening in the floor made by these passenger elevators and by the staircase taken together was almost as large as the opening in the center of the building. Their location is shown on Fig. 1, and more particularly on Figs. 3, 4, 5 and 6. Undoubtedly, these vertical openings produced a draft, fed from every broken window, which intensified the heat of the fire and its destructive effects manifold.

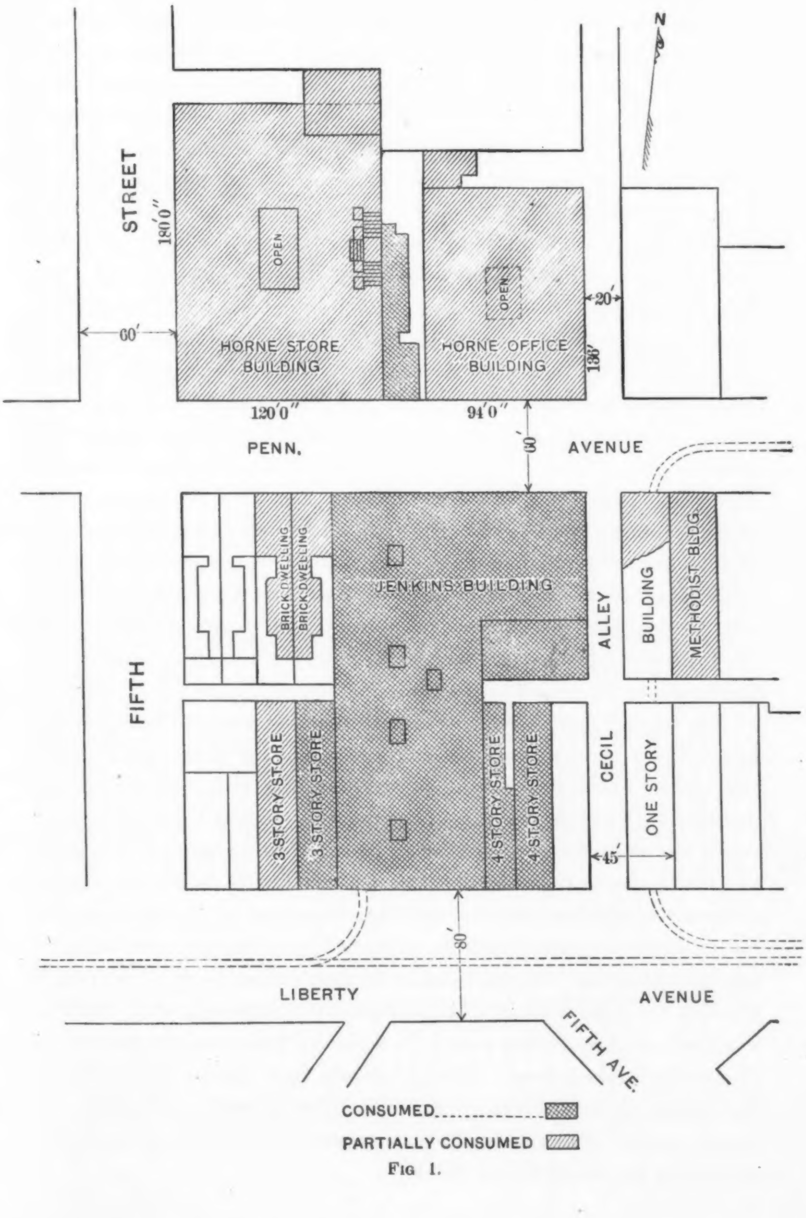
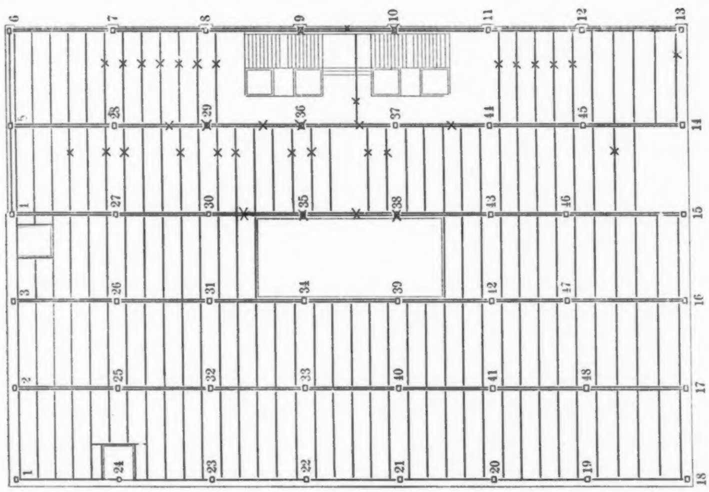

N
STREET
180'0"
60'
OPEN
HORNE STORE BUILDING
OPEN
HORNE OFFICE BUILDING
20'
136'
120'0"
94'0"
PENN.
60'
AVENUE
BRICK DWELLING
BRICK DWELLING
JENKINS BUILDING
ALLEY
BUILDING
METHODIST BLDG
FIFTH
3 STORY STORE
3 STORY STORE
4 STORY STORE
4 STORY STORE
CECIL
ONE STORY
45'
80'
LIBERTY
AVENUE
FIFTH AVE.
CONSUMED
PARTIALLY CONSUMED

FIG 1.

The entire building was occupied by Horne's retail dry goods store. The windows on Penn Avenue are as large as it was possible to make them, and they were entirely unprotected, either by shutters or sprinklers. All the floors and the east and west walls were supported by steel columns made of Z-bars and plates the same, or approximately the same, as the Carnegie "Standard." The arrangement of these columns and of the girders and beams which support the floors is shown in Figs. 2, 3, 4, 5, 6 and 7.

The framework of the building was very heavy. These figures show the beams and girders which remained in place after the fire. The interior girders were 24 ins. deep, with double 22-in. web plates, 3 x 3-in. flange angles and 15-in. cover plates. The beams were all 15 ins. deep, carried on brackets riveted to the side of the box girders. These beams were not connected to the girders at all through the top flange or web, and by only two rivets through the bottom flange. The girders were fastened to the columns by two rivets in the bottom flange and two rivets in the top flange. The detail of these connections is shown in Fig. 8. The wall girders along Fifth Street were 20 ins. deep, with 3 x 6-in. flange angles and 7-in. cover plates. These girders carried the wall from floor to floor, and were completely covered by the brick masonry on the second, fifth and sixth floors. On the third and fourth floors they were, however, somewhat exposed on the inside to the action of the fire.

The east or party wall, shown with the west wall in Fig. 9, was also carried from floor to floor on the girders, but the front wall was self-supporting the entire height of the building, and the rear wall was nearly so. The horizontal parts of the front wall at the floor lines between the windows were carried on iron lintels resting on the piers, and not fastened to the steel frame. These lintels on most floors were close to the windows and exposed to the action of the fire. In the fourth story they were partially protected by a course of terra cotta, but the latter was fastened in place by iron anchor bolts which passed through the terra cotta so as to be themselves exposed. Fig. 10 shows two sections through the rear wall, a part of which was supported on iron at the second floor. This is shown by a dotted line in Fig. 1. The ceiling in the sixth story was suspended from the roof beams. It was composed of $1\frac{1}{2}$ x $1\frac{1}{2}$-in. T-bars, spaced about 12 ins. apart, carrying a solid tile about $1\frac{1}{2}$ ins. thick.



2nd FLOOR FRAMING
FIG. 3

NOTE: THIRD FLOOR ABOUT THE SAME AS SECOND FLOOR.

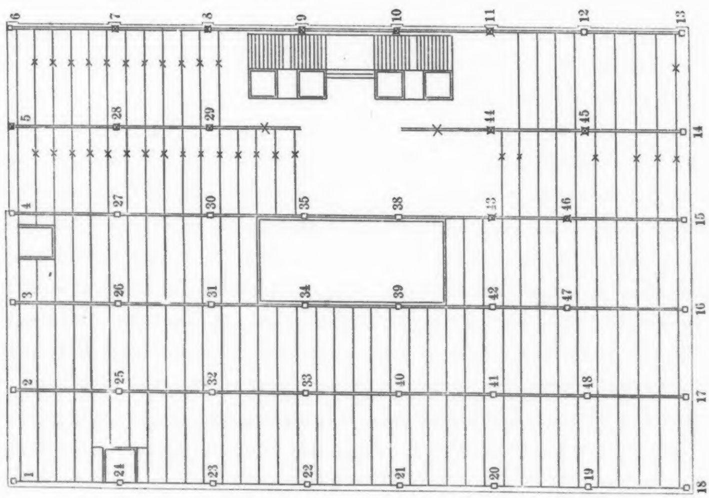
1st FLOOR FRAMING
FIG. 2.

The street walls were faced with pressed brick and terra cotta trimmings above the second floor. Below the second floor these walls were finished with Indiana limestone. The cornice at the roof level was made of copper, supported on wooden outriggers. The sidewalk was made of stone, resting on steel beams.

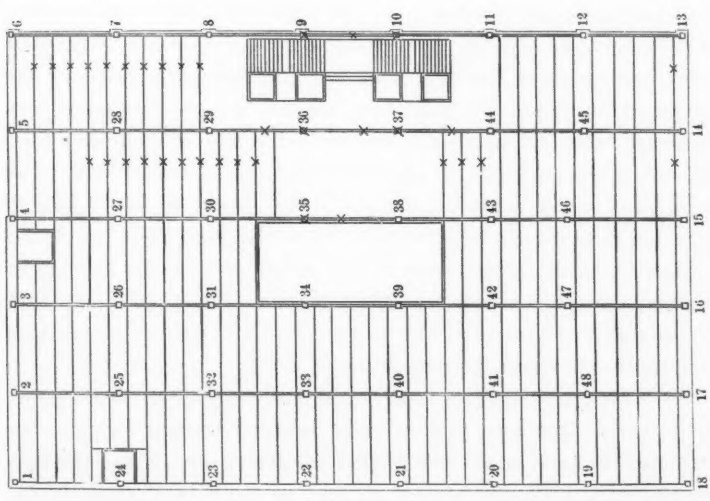
All the fire-proofing in the building was made of hard-burned material. The floor arches were 9 ins. deep, supported at each side by skewbacks especially designed to cover the entire side of the beam, and the joint between the arch proper and the skewback was made so that the top of the arch was flush with the top of the beam. The walls of all of this material were about $\frac{5}{8}$ in. thick, and the sections of the arches were of the old style side construction. The columns were covered with tile 2 ins. thick, having one hollow space and walls $\frac{1}{2}$ in. thick. All of this material was well erected. The floor sleepers, spaced about 14 ins. apart, were bedded in cinder concrete which covered the arches 4 ins. in depth, and the floor was finished with hard pine. This construction is shown in Fig. 11.

The first fire alarm was a little before midnight on the night of May 2d. The Jenkins Building was occupied by the Jenkins Wholesale Grocery Company, which carried a very heavy stock of oils and other things which were extremely inflammable; moreover the interior of the building was constructed entirely of wood. An effort was first made to save this building, but as soon as it was determined that it would be impossible, the attention of the firemen on Penn Avenue was directed to the Horne Buildings, and they started to carry hose to the roof of the Office Building. Before this could be done, however, the entire front of the Jenkins Building on Penn Avenue fell into the street. The fire was pushed, as it were, into the street. Its flames leaped entirely across to the fronts of the Horne Buildings, consuming some of the apparatus of the Fire Department, cracking and melting the glass in the windows, and setting fire to everything that could be consumed in these buildings adjacent to the windows. With a suddenness that can scarcely be conceived, the entire contents of the Horne Store Building were on fire, and in less than half an hour they were entirely consumed. On the four upper floors scarcely a vestige of woodwork of any kind was left in the building, and on the two lower floors it was almost as bad.

The tank on the roof fell to the first story and carried with it a



5th FLOOR FRAMING
FIG. 5.

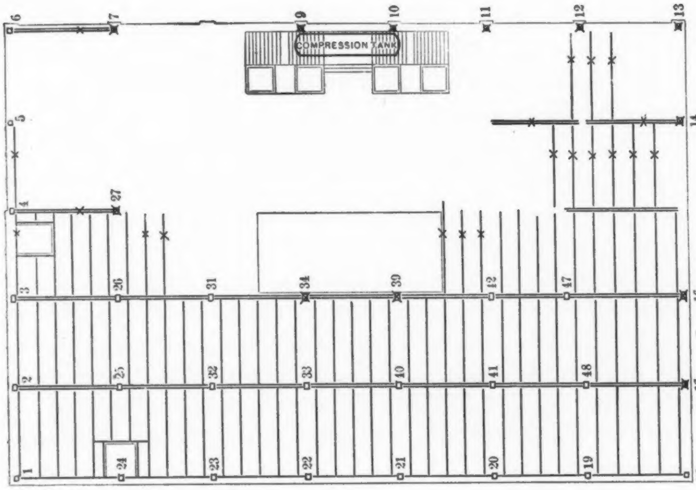


4th FLOOR FRAMING
FIG. 4.

large section of the steel construction, bending, tearing and breaking the adjacent columns and beams and pushing out the adjoining wall. The front of the Jenkins Building fell about 1 o'clock. Practically no water was thrown into either of the Horne Buildings until the fire in those buildings had spent itself. By 3 o'clock the firemen were able to get into the Store Building and throw water on the vaults. The face brick on Penn Avenue on both the Horne Buildings endured the fire well and was injured but little. The cut stone and terra cotta, however, were both very badly cracked and flaked off by the heat, and on this account the entire front wall had to be taken down, that which stood the fire well, together with that which did not. It would be interesting to know how much of this injury to the terra cotta was due to the water being thrown upon it while it was hot, but it is impossible to get any information on this point that would be conclusive.

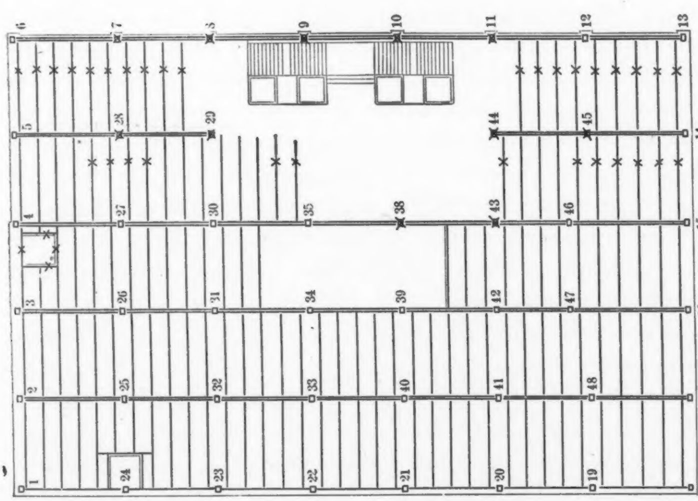
Some of the exterior lintels where the span was long and the iron not very heavy were bent so they can not be used again. The light T-bar framing for the suspended ceiling in the sixth story was bent and warped by the heat so that it will have to be taken out. Some of the lighter framing around the opening in the middle of the building was also injured. All the beams marked on the plans with a cross need straightening or fixing in some way before they are used again, while the beams and girders completely destroyed, and omitted from the framing plans, will of course have to be new material. This data is reproduced from the report of the engineers appointed by the adjusters to examine the buildings and decide upon the exact loss. From the basis of this report the author would estimate the total value of the steel work in the building to be about $80 000. The engineers reported a loss of $18 530, which would be about 23% of the whole value of the structural iron in the building. All of the iron, even where covered, must have been heated to a very great heat, for where the tank fell some of the columns are bent as though they were wax, and the paint on the ironwork of the columns remaining covered also shows the evidence of it.

The cinder concrete over the floor arches was entirely decomposed by the heat. The tops of the arches which remained in place are everywhere in good order, but a large portion of that part of the arch that makes the ceiling is broken off, leaving the hollow spaces in the arches opening out into the story below. The skewbacks are also



ROOF FRAMING

Fig. 7.



6th FLOOR FRAMING

Fig. 6.

broken badly. In general, the covering of the columns in this building remained intact, but the plastering was ruined everywhere. All of the fire-proof in the building will have to be replaced; the east wall back of the elevators, which was pushed out of plumb by the falling tank, will have to be taken down and rebuilt, and repairs will have to be made in the Fifth Street wall. The cornice is a complete loss, largely owing to its being supported with wood. Nearly half of the roof was entirely torn out by the falling tank, but where it remained in place it seemed to be uninjured. The rear windows were provided with wooden shutters covered on both sides with sheet iron. The wood in all of these shutters was charred; and the iron was warped badly, though in almost every case the shutters held in their places until after 3 o'clock, when the fire was entirely under control. Without question they must have aided greatly in preventing the fire from spreading to the adjoining buildings in the rear.

Plate XVIII, Fig. 1, shows the condition of the Store Building after the fire, and Fig. 2 is a view on the first floor of the same building looking from the center of the building towards the fallen tank, which shows quite clearly in the background. This picture also shows the construction of the light court and the railing or balustrade which surrounded it. Plate XIX, Fig. 1, is also taken on the first floor, but looking in the opposite direction. It shows the ceiling and some of the broken tile. The floor arches did not endure the fire as well on the upper floors as they did on this. Plate XIX, Fig. 2, shows in the foreground how the terra cotta was flaked off and broken around the windows in the Store Building. In the background on the right it shows the ruin of the grocery store, the one-story building through which the street cars go, and the side front of the Methodist Building. This picture was taken several weeks after the fire, and the repairs to the window frames and windows in the latter building had already been completed.

The Horne Office Building was not as large as the Horne Store Building, and was only four stories high. It was built in 1894. The entrance to the office portion of the building, the third and fourth floors, was on the extreme western side of the building. In the basement, in the first story, and in the second story, the remaining portion of the building was divided into four parts by solid partitions extending from the front to the rear of the building. The western part was

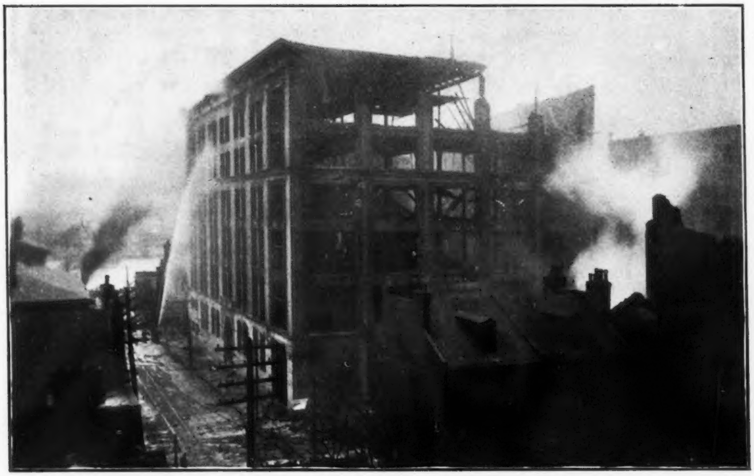


Fig. 1.

Fig. 2.

occupied by a drug store, the part adjoining this by a millinery store, the next part by a carpet store, and the eastern part by a china store. Each of these stores occupied its apartments in the basement and in the first and second stories. There is also a court in the building similar to the one in the Store Building, but it only extends to the third floor.

The evidence of the firemen agrees with what the very nature of the construction would indicate as to the way the fire burned in the two buildings. In the Store Building the draft was in from the outside and up through the center. In the Office Building it was directly through these tunnel-like shafts on the first and second floor from the front to the rear of the building. Each floor of each store was like a

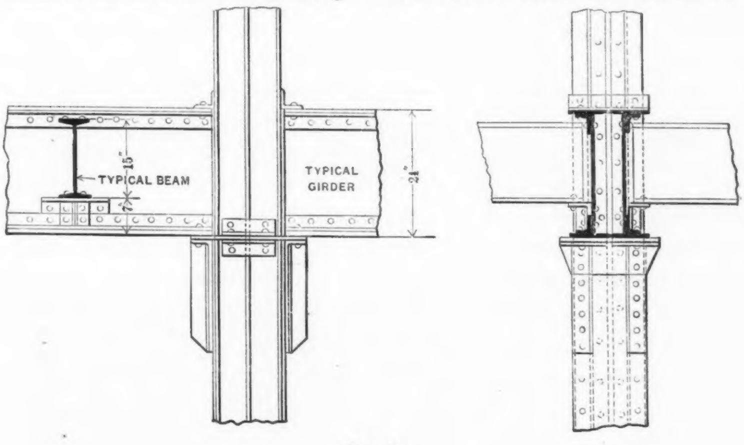


FIG. 8.

long flue, and all the contents and woodwork used in the construction were entirely consumed.

In some respects the construction of the building was similar to the construction of the Store Building. The floors were carried on 15-in. beams and Z-bar columns; they were also covered with cinder concrete and finished with wood flooring. The floor arches were 9 ins. deep, supported on skewbacks similar to those in the Store Building. The ceiling of the top story was made of light blocks of fire-proofing supported on T-bar construction. In other respects, however, the construction was radically different from that in the Store Building. The girders were made of double 20-in. beams. The exterior walls

were self-supporting. The floor arches were end construction instead of side construction, and, what is most worthy of notice, they were made of porous material instead of hard-clay material. A section of the floor is shown in Fig. 12.

The column covering, the ceiling of the top story, and the partitions were also made of the porous material. The column covering, however, was about 1 in. thick and solid, instead of 2 ins. thick and hollow. The walls of the floor arches were generally $\frac{3}{4}$ in. thick. All the partitions in the building were supported near the floor on a wooden frame. The front wall of the building was finished with Indiana limestone up to the second floor, and with pressed brick above the second floor. Three of the piers extended down to the sidewalk, and three of them started at the second floor and were supported in the first story by cast-iron columns. Plate XX gives two elevations of the front of this building, showing these features of the construction, and the division of the building into the entrance and four stores.

Owing to the partitions on the third and fourth floors the fire did not do its work as completely as it did in the story below, but everywhere in the front of the building and in places entirely through the building every vestige of woodwork was completely consumed. This was particularly noticeable wherever the fire had a chance to get a draft through the building. In the stores and in the offices, wherever the fire burned the hottest, the woodwork was so completely burned out that nothing was left of the floor sleepers, which were almost completely bedded in concrete, and the framework in the partitions was also entirely consumed. Plate XXI, Fig. 1, shows a corridor on the third floor where the partitions obstructed the progress of the fire most, and yet it will be noticed the wood was nearly all burned through.

The steel construction is almost entirely uninjured. A few angle bars about the court and a few lintel beams in the front wall are all that will need replacing, and this will cost only a few dollars. The floor arches were also in good condition. The damage is almost entirely confined to the bottom of the skewbacks which covered a portion of the beams. This is shown quite clearly in the illustration of a portion of the ceiling in the second floor, in Fig. 2, Plate XXI. This picture is taken in about the worst place in the building. The bottoms of the tiles in the arch proper were not broken out as

FIG. 1.

FIG. 2.

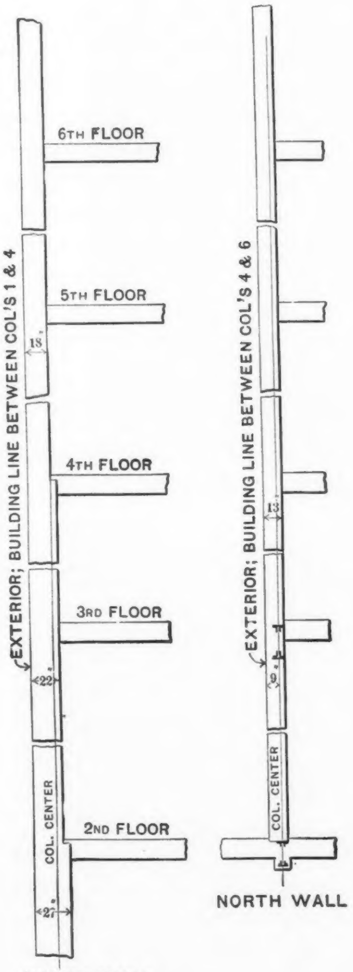

6TH FLOOR
5TH FLOOR
4TH FLOOR
3RD FLOOR
2ND FLOOR
EXTERIOR; BUILDING LINE BETWEEN COL'S 1 & 4
18"
22"
27"
COL. CENTER
NORTH WALL
EXTERIOR; BUILDING LINE BETWEEN COL'S 4 & 6
13"
9"
COL. CENTER
NORTH WALL

Fig. 9.

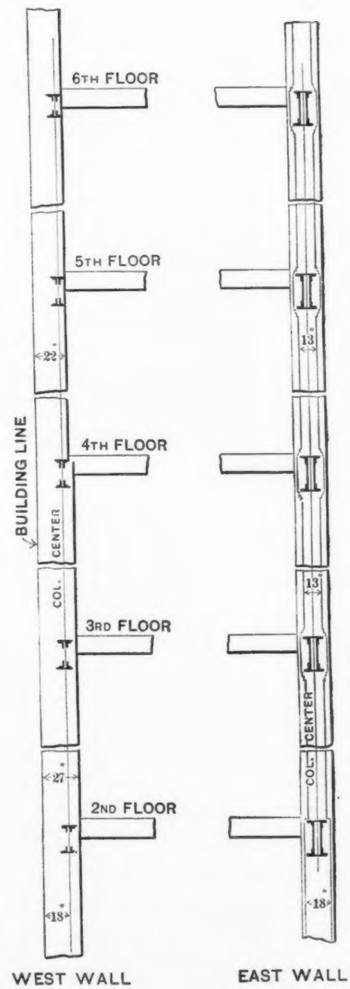

6TH FLOOR
5TH FLOOR
4TH FLOOR
3RD FLOOR
2ND FLOOR
BUILDING LINE
COL. CENTER
22"
27"
18"
WEST WALL
13"
13"
COL. CENTER
18"
EAST WALL

Fig. 10.

they were to a great extent in the Store Building. The column covering also stood the fire remarkably well, considering the shape of the tile that was used for the purpose. The partitions between the stores nearly all remained standing in spite of the fact that where the wood burned out the opening extended from column to column. A fair example of this is shown in Plate XXII, Fig. 1. Some of the partitions in the offices stood the same way, but many of them sagged down when the framework burned out, and a few were entirely broken down. The cinder concrete was also entirely ruined, but the ceiling in the fourth story was injured very little, and the roof, excepting the skylight and some of the flashing along the front wall, is left as good as before the fire. Even the light trusses over the court are entirely uninjured.

The Methodist Building was also built in 1894. It is long and

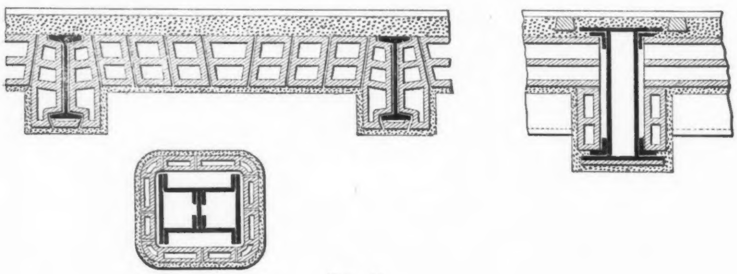


FIG. 11.

narrow and very much smaller than either of the other buildings, covering only about one-fourth as much ground as the Horne Office Building, and about one-sixth as much ground as the Store Building. It is eight stories high, occupied by a book store on the first floor, and by offices on the other floors.

By reference to Fig. 1 it will be seen that the broad side of the building was exposed to the fire. The offices were all on this side of the building running back to a hall and stairway on the other side. The construction of the building in almost every particular was different from that of the other buildings. The exterior walls were made of brick with sandstone trimmings, self-supporting. There were no interior columns in the building, but columns in the walls supported 20-in. beams spanning the entire width of the building. These beams were supported about 16 ft. apart, and carried floor arches without

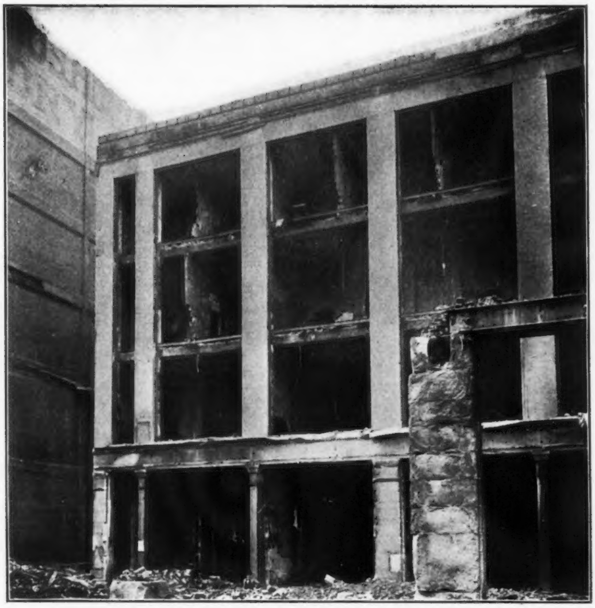


Fig. 1.

Fig. 2,

the use of joists or other intermediate beams. These floor arches are composed of a solid bed of concrete about 8 ins. thick, made of Portland cement and slag, and strengthened with imbedded wires extending over the tops of the 20-in. beams. The whole construction is so designed that the top of the concrete is about flush with the tops of the beams, as shown in Fig. 13. That portion of the beams projecting below the arch is also boxed in with concrete of the same kind. All the partitions in the building are made of 2 x 4-in. wood studding in the ordinary way, covered with wire lath on both sides and plastered. The spaces between the studding are not filled. The ceiling of the top story is made of wood, suspended and covered with wire lath the same as the partitions.

The fire seems to have been greatest in the top story and nearly as bad in the two stories below. The windows in the east wall of the Jenkins Building facing the Methodist Building were provided with

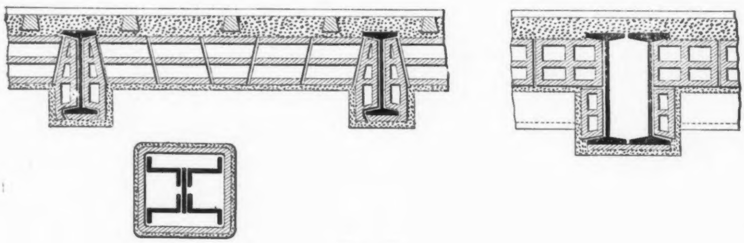


FIG. 12.

iron shutters. The rear portion of this wall did not fall during the fire. This was a great protection to the Methodist Building. The front portion of the east wall of the Jenkins Building fell shortly after the wall facing Penn Avenue fell, and nearly all of the window frames in the Methodist Building at once took fire. As the entrance to this building and the stairs and halls are all on the side furthest from the fire, the firemen could take their hose into the building and fight the fire on each story from the inside. There was no room in this building where the woodwork was entirely consumed. The wood in the floors was burned only in a few places. The ironwork and the concrete in the floors were not seriously injured. A very small expense will make the former as good as new, and all of the concrete floors can be used again, though the owners are putting in some additional beams for their support. The floors are deflected. They have evidently

been so since the building was erected, though the deflection seemed to the author to have been somewhat increased by the fire. The partitions offered but little resistance to the fire and are badly damaged wherever the fire made an entrance to the building. The ceilings also suffered severely.

A careful study of the illustrations from Plate XXII, Fig. 2, to Plate XXIV, Fig. 2, inclusive, tells the story of the fire in this building better than words. Plate XXII, Fig. 2, shows the rear part of the east wall of the Jenkins Building still standing after the fire, and the firemen throwing water on the fire from the roof of the one-story building, between the Methodist Building and the grocery. Plate XXIII, Fig. 1, shows one large room on the eighth floor, the interior of an architect's office; Fig. 2 on the same plate is a room on the seventh floor. Plate XXIV, Fig. 1, is another room on the seventh floor, and Fig. 2 is a room on the sixth floor.

So much for the construction of the buildings, the fire and its

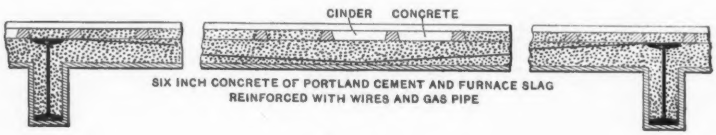


FIG. 13.

effects. In entering upon a discussion of the relative merits of the different buildings, the different materials used in them, and the lessons taught by the effects of the fire, it may be well first of all to call attention to serious faults in the construction in all three buildings, which were inexcusable and greatly increased the loss pertaining to the buildings themselves.

The sound value of the Store Building is estimated by the insurance adjusters to be \$367 980, while the total damage is given at \$206 747. This is exclusive of boilers and dynamos. The loss to the steel construction, as reported by the board of engineers appointed by the adjusters, as stated before, was \$18 530, that is to say, the loss in the steel construction was about $8\frac{1}{2}\%$ of the whole loss, or, as previously stated, about 23% of the whole value of that part of the construction. Out of 336 columns in the building, counting each story separate, 13 were entirely destroyed, and 48 were injured so as to require fixing and re-erecting. Four heavy girders were also ruined,

FIG. 1.

FIG. 2.

and 18 others were injured. These figures are made up from the engineers' report before referred to.

The location of the tank on the roof is shown in Fig. 7. It was 6 ft. in diameter and 25 ft. long, made of steel plates $\frac{5}{16}$ in. thick in the cylinder and $\frac{1}{2}$ in. thick in the heads, and had a capacity of about 5 000 galls. In working, however, only about half of this should be figured on, and the total weight of tank and contents when it fell was therefore probably not more than 30 000 lbs. It was supported by roof beams which were carried at one end by the girder between columns 36 and 37, and at the other end by the wall girder between columns 9 and 10, and enclosed with a tile wall and asphalt roof. The four beams under the tank were 15 ins. deep. The roof here, as elsewhere, was protected only by the suspended ceiling. None of the roof framing was fire-proofed, and no exception was made of the beams under the tank. The intensity of the heat at this point was also greater, for it was at the top of the flue. Whether the beams or the columns gave way because the factor of safety in them was not as great as it should have been, or the heat was simply too great for anything to withstand, and the absence of fire-proofing is alone to blame, matters little. The fact remains that good fire-proofing would undoubtedly have saved the tank, and if the tank had not fallen at all, the loss of the steel construction would have been, as estimated by the adjusters, not more than 5 per cent.

A careful examination of Figs. 3, 4, 5, 6 and 7, will show that more than one-third of the roof was torn away, as were large areas on all floors, decreasing from top to bottom. One cannot help asking why beams so distant from the tank were torn out by the fall. It should be particularly noticed, too, that the tank fell in a comparatively open place where the framing laterally was much weaker than elsewhere. Why, also, did the beams give way more than the girders, and why was the wall bulged out at all? It seems to the author that if the beams, girders and columns had been connected to each other, somewhat proportionately to the strength of the members themselves, the tank would have gone down through the stairs with very little injury to the structural iron work or the wall, and, at the most, this part of the loss would not have exceeded \$5 000. As it is, 16% of all the beams had to be replaced, and 14% of them had to be straightened or fixed. The use of $\frac{1}{4}$-in. metal in the top tier of columns is also, to say

the least, a dangerous practice. It is more than possible that these columns were the first members to give way.

Another particularly discreditable piece of work in this building has already been referred to, the use of wooden outriggers to support the copper cornice. The loss on the cornice is not given, but it must have been quite an item.

In the Office Building there is another grievous fault in construction, but in this case in the partitions. It is a fault, too, which has been repeated again and again in buildings which are counted fire-proof. All of the partitions in this building must be taken down, and it is a pity, too, for, except the injury due to the burning of the wooden frame on which they rested, most of them were as good after the fire as they were before. This frame was put in to nail the baseboard to, but was not needed, for the porous material in the partitions will hold a nail nearly as well as wood.

The greatest fault in the construction of the Methodist Building also concerns the partitions. If this building had had a quarter of the heat that the other buildings had, every partition would have been completely destroyed. The fire seems to indicate that plastering will not prevent the heat of a great fire from charring a wooden frame behind it, even if it does not come off and expose the wood, and such work is not fit to be reckoned as fire-proof construction. All of these are faults which were scarcely matters for question. The knowledge and experience of architects and builders had already covered this case, and the fire can now only emphasize it.

Nevertheless if all these faults in construction had not existed, the buildings would have been injured, and the contents of the stores, at least, in both the Horne Buildings, would have been burned. They offered little resistance to fire because the glass in the windows broke into pieces and in some places melted, immediately after the front wall of the grocery building fell into the street.

The firemen could not for a moment stand the heat, which they claim was hotter than any of their oil fires. They scarcely saved their engines and their lives, and they had, in some cases, to turn the water on each other, and even then some of them were burned. The heat on the building on the opposite side of Fifth Street, which was exposed to only a fraction of the intense heat of the grocery store, turned the water thrown on it to steam, so that the firemen worked at a disadvantage

FIG. 1.

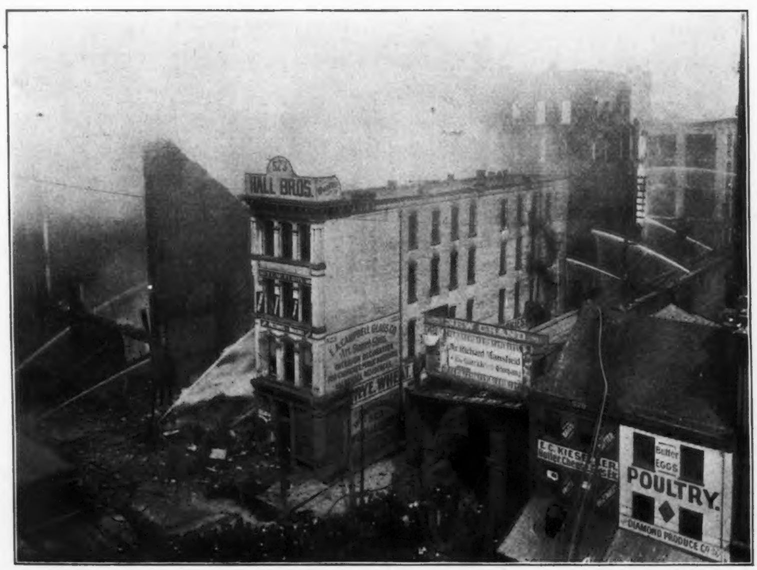


FIG. 2.

in not being able to see well. Under these circumstances, there could be no hope for the contents of either of the Horne buildings.

It seems, therefore, as if the first problem is the protection of large windows, and that, perhaps, the most important lesson of this fire is the necessity of that protection. It is not so important in some New York and Chicago buildings as in cities like Pittsburg, for in the former there are so many incombustible and fire-proof structures that a heat great enough to break glass across the street is not likely to occur, whereas in smaller cities having only a few buildings of modern type, in many cases surrounded on all sides by buildings built largely of wood, the danger to glass areas is greatly increased.

It seems as if ingenuity ought to furnish some practicable scheme for protecting large window openings. The shutters in the rear of the Horne store did most excellent service and the covering was only thin sheet iron. Why should not all windows in fire-proof buildings be provided with iron window frames, and iron sash and metallic or asbestic rolling shutters of some character? The solid folding shutter is objectionable on front openings because it disfigures the building, and if they are on the inside of a window, they prevent a proper use of it.

Without question automatic sprinklers or other water safeguards against fire have had a large sphere of usefulness, and might be devised as a special protection to show-windows. It seems, however, as if the shutter should be of some solid material. Firemen would not hesitate to enter a store and fight any fire behind a solid barrier, and in all but the worst cases such assistance would scarcely be required. Besides this, if a solid barrier secured the protection, there might be no loss to contents; whereas the damage by water in a stock of merchandise might be as bad as the loss from fire. One of the principal points made in reference to the sprinkler is that a pail of water at the beginning will extinguish any fire and that the sprinkler itself furnishes that first pail of water. The automatic fuse is, therefore, made to act at a very low temperature, say 150°, while the heat on a show window in such a city as Pittsburg may exceed 1 000°, or, in rare cases, double that amount.

Some of the best buildings have iron window frames and sash, and other buildings with large windows, larger than these in Pittsburg, are provided with rolling shutters. Wood frames and sash are used,

generally because of their economy, and consequently it is not only a question of "how," but subsequently a question of persuading each owner to meet the additional expense.

Some reports of the fire have condemned the large openings, but who can say that the fire would not, under the same circumstances, have spread with equal rapidity through smaller openings. Reform in buildings cannot be conducted along lines which shut out the light or deprive the building of its architectural design. The end must be accomplished, if it is accomplished at all satisfactorily, by protecting the windows and not by changing their size. In dark cities, like Chicago and Pittsburg, the large light areas are exceedingly important and are one of the chief advantages of modern building methods.

Kindred to this evil of unprotected window openings is the open shaft through the center, which practically makes one room of the entire building. Indeed, so far as the progress of the fire is concerned, it is worse than one room. Insurance men have long recognized that large store buildings open over entire floors, and through all stories are a dangerous fire risk, and must remain so unless some satisfactory method can be designed of dividing the space either permanently or when not in use. The insurance adjusters in their report suggest that such light shafts might be protected by an asbestic covering made to roll up and come together in the center. Such an arrangement would close the shaft at each floor level. In this particular case the fire undoubtedly entered through the windows at one time on all floors. The open shaft did not prevent the destruction of the contents, but only intensified the heat on the upper floors. If, however, the fire should start in such a store on the lower floor, and was not almost immediately extinguished by a fire service of some sort, the chances are altogether probable that the open shaft would be the means of the destruction of the entire contents of the building; whereas, if the floors could be closed by some simple mechanism, such a fire could be confined to the floor on which it originated.

It seems to the author that, however perfect a scheme can be worked out for fire protection by the use of water, the importance of separating floors from each other, at least in an emergency and when not in use, and indeed separating stores into parts in the same way, would still be vitally important.

FIG. 1.

FIG. 2.

One of the most important object lessons relating to the fire pertains to the fire-proofing.

The fire teaches nothing as to the real fire-proof qualities of good concrete in floor construction, for the floors in the Methodist Building were not subjected to a real test. The heat on the outside of the building was only a fraction of what it was on the other buildings, as testified to by the firemen and by the fact that the stone trimmings in the exterior walls exposed to the heat were injured in only three small places, while the fire on the inside was confined to an area entirely controlled by the fire department. Whether ordinary concrete, or, for that matter, concrete of any kind, will resist more fire and cold water than brickwork or other forms of burned clay is undetermined and debatable. Certainly this fire does not prove that it will or that it will not.

As between the burned material and the porous, however, the superiority of the latter as now manufactured and used was clearly illustrated. The author ventures the definite statement, that partitions of 4-in. hollow porous material made of sawdust and clay properly manufactured and properly put in place, column covering made in the same way at least 3 ins. thick, and floor arches of the same material deep enough for flush ceilings, with properly designed skewbacks and beam flange protection, will stand any possible combination of heat and water, without material injury. It seems to him that the fire in the Athletic Club Building at Chicago proved this, as does the fire at Pittsburg.

The same thing cannot be said, however, in regard to hard-burned clay material, as it is now manufactured, especially in the West, where, in the interest of economy, it has been made lighter than in the East, though in theory it ought to make satisfactory resistance to fire, for it is incombustible and hardened with heat, and brick which is made in the same way can be relied on to stop a fire. Yet not this fire alone, but others have demonstrated that the hard material will crack and fall to pieces under great heat, even if it is not suddenly cooled with water thrown upon it.

The fire-proofing work in the store, both in the arches and around the columns, was erected well. Indeed, it was probably erected better than in the average New York building, and the damage to the fire-proofing in that building is primarily due to its being hard material

instead of porous. The covering of the girders and beams which projected below the ceiling line was pretty generally broken, and this must have been due in a large measure to the fact that the ceiling was not a level surface, though the loss was, without doubt, increased on account of the very few divisions in the tile and the very thin walls. The material used in New York is all thicker and heavier than this was, and on that account would probably stand a fire better. That the damage to the fire-proofing is primarily due to its being hard tile instead of porous is, however, shown by a comparison between the two Horne Buildings. In both cases the ceiling was paneled. In the Store Building the bottom of the hard tile arches was broken by the fire, whereas in the Office Building there was scarcely any injury of that kind. The insurance adjusters state that there is only a salvage of $16\frac{2}{3}\%$ in the fire-proofing of the Store Building, but that they believe if the tank had not fallen, the salvage would have been at least 50 per cent.

A satisfactory fire-proofing material when properly constructed in all its details should not suffer a loss of more than 1% or 2% at the most.

The fire-proofing in the Office Building suffered much more than this, but in every case there is a special cause for the injury, entirely independent of the quality or texture of the material. The adjusters report 43% loss on the partitions, and this is low when it is remembered that every partition in the building was left unsupported by the burning out of the wooden frame. The column covering resisted the fire unexpectedly well, but the single thickness of material makes a wretched covering, and it should all be replaced with hollow blocks. In places, as shown in Plate XXI, Fig. 2, the skewbacks covering the beams projecting below the arches suffered severely. If the insurance companies were required to replace all these broken pieces, it would necessitate the removal of arches which were entirely uninjured. The author has not been able to account for the large percentage of damage allowed by the adjusters on this part of the fire-proofing, $33\frac{1}{3}\%$, on any other supposition, for in his examination he found practically none of the arches injured, and the contractors in rebuilding have furnished only 300 ft. of new arches, while there are 40 000 ft. in the building.

Besides this, which is perhaps the most important observation in

FIG. 1.

FIG. 2.

regard to the fire-proofing, the following conclusions seem also to be warranted.

The breaking of the hard tile arches on the bottom is due to the inability of the materials to withstand inequalities of contraction and expansion, and it breaks in the corners, both because the strain is greatest and the tile is weakest there. There is an inequality of expansion because it is heated only on one side. The strain is greatest in the corners because the expansion of one side tends to shear that side from the adjoining ones, and it is weakest at the corners because if there is any initial stress in the material it would more naturally occur there than elsewhere, while the very fact that it breaks in that particular place more than anywhere else indicates that it is lacking in strength along the edges. The report of the board of expert engineers appointed by the appraisers furnishes some valuable facts, but some of their observations seem to the author extremely fallacious, and quite so in regard to this point. They state in effect that the scaling off of the lower web of the floor arches is due to the lateral motion of the iron work caused by the heat of the fire. A panel surrounded by iron will enlarge in area if the iron expands, and if it is true, as they claim, that the iron expands more than the arches, the process of expansion would seem to relieve the arch, in whole or in part, instead of bringing any strain to bear upon it tending to its destruction. The damage to the tile is also not due to the subsequent process of construction, for, as a matter of fact, the damage to the tile occurs during the fire and not after it.

The tendency of the times is to make the material too light. If the walls of the material were made thicker, it certainly would add strength. Possibly, also, if the angles on the inside were rounded more, the strength of the corners would be increased. Checks and cracks in the corners of the blocks as delivered from the factory may not be particularly objectionable, so far as support to the floor is concerned, but they are objectionable in resisting fire effects, and such tile will go to pieces sooner than that which is free from such imperfections.

Possibly some clays of which hard-burned fire-proofing material are made have more strength than others, and, on this account alone, the effect of the fire in one case can be no certain criterion of what the exact effect will be in another case, and the thickness of the walls and

the various parts of the material might possibly be lighter with some clays than with others.

Unbroken flat ceilings should always be preferred to panel work with beams projecting below, no matter in what way they may be protected. This fire greatly emphasizes this fact. The exposed area is increased when floors are built as they were in the Horne Buildings, and, besides, the panel forms a pocket which confines the heat and makes it more effective. An even surface deflects heat as it does light, and if the surface is even, the covering of the beams where protection is most needed will not suffer the worst punishment as it did in the Horne Buildings. The fact that the beams which were uncovered by the action of the fire were not deflected and ruined is no reason why they should not be covered so that the tile will not come off in any kind of fire.

The bottom of the arch should also be low enough under the beam to permit the bottom flange to be covered with a hollow tile, or, at least, with a solid tile having an open space between the covering and the beam. As the material is now manufactured, this is rarely accomplished, and the workmanship in putting the beam covers in place is often bad. It seems as if there might be an improvement in this direction, and that the material should be designed in such a way that it will not only be theoretically good, but so designed that the beam cover cannot possibly be improperly placed.

All partitions and all column covering should be built on the arches. Cinder concrete which will crumble away is not much better for support than wood which burns away. Builders may object to such a provision, but it would not be a great hardship or add materially to the cost.

Wood should not be used in partitions in any way whatever. Iron should be used to frame all openings.

The insurance adjusters have also called attention to the fact that the damaged limestone in the first story of the Horne Buildings requires the pulling down and rebuilding of much brickwork which was entirely unharmed. They state that there would not have been more than 15% loss in the brickwork if other members had stood, whereas the loss is actually at least 40%, the excess being due, it is presumed, to the falling of the tank and the taking down of good walls on account of the broken terra cotta and stonework.

They also call attention to the broken sidewalk, which was a total loss, and state that if the beams had been filled in with brick arches and finished with cement, the loss would have been very small.

All experts who have examined into the matter carefully seem to agree that the fire demonstrated the success of the steel-frame method of construction.

The general public is not sufficiently informed or is not careful to discriminate as to exactly what is meant by the words fire-proof construction, and so it naturally questions the success of fire-proof buildings. If by fire-proof buildings are meant those that will prevent inflammable contents from burning, and, to some extent, from injuring the structure itself, when the fire is once started on the inside, the answer must always remain "no," and the public might as well understand it. The expression "fire-proof building" should properly be defined as a building which will not burn, no matter how great a fire it may be exposed to from without, and which will confine an internal fire to any room in which it occurs, without material injury to the rest of the structure.

In this sense of the word buildings can be made fire-proof, and the fire at Pittsburg rather confirms that opinion than otherwise.

No attempt has been made in this paper to get at the exact temperature of the fire, first, because the examination of the buildings was made too late to do so with any degree of satisfaction, and also because the conclusions arrived at are not necessarily dependent upon the exact temperature. In every discussion it must be taken into account that no two fires are alike. It is the unexpected that always happens, and the only measures that can be depended upon are those designed to meet extraordinary conditions which must always be to a certain extent assumed.

In conclusion, a recapitulation of the most important points intended to be brought out by this paper may not be out of place.

The best design, the best specifications, and the best workmanship in every detail of the construction of a building, are quite essential to making it a fire-proof structure which can be depended upon in any emergency.

The whole exterior of a building should be built of materials that will not be injured by heat. This fire would point to brickwork as the most desirable material, and without question throws

terra cotta under a cloud. This observation should cover the windows as well as the walls, and points to something new and better than has yet been used to any great extent in building operations.

Large store buildings, open over entire floors and through all stories, must always be a dangerous fire risk, and if it is important that large apartment stores should occupy such quarters during business hours, the only way to give them any satisfactory security against fire must be in subdivision of departments with fire-proof curtains or some other movable divisions that can be quickly and easily operated.

As now manufactured porous tile or terra cotta fire-proofing can be relied upon to protect the steel construction, while the hard-burned material cannot be depended upon with the same certainty.

Woodwork covered with wire lath and plastering is not fire-proof construction, and the efficiency of concrete in floors was not tested by this fire.

MEMOIR OF DECEASED MEMBER.

NOTE.—Memoirs will hereafter be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

FRANCIS ASBURY LYTE, Assoc. M. Am. Soc. C. E.*

DIED JUNE 24TH, 1896.

Francis Asbury Lyte was born in East Lampeter township, Lancaster County, Pa., on March 6th, 1854. His education was obtained in the public schools of the township, and at the Pennsylvania Normal School at Millersville. For about two years after graduating he taught school at Ebensburg, Pa. His engineering career did not commence, so far as can be learned, until 1881, when he was engaged as chainman for the Pittsburg, McKeesport and Youghiogheny Railroad. He rose rapidly through the grades of rodman, instrumentman and assistant engineer to that of first assistant engineer. From March, 1882, to September, 1883, he was in charge of a transit party for Baker & Gilmore of Minneapolis, Minn.; in September, 1883, he was associated with F. L. Straw in the purchase of the good-will of his employers, and for somewhat over a year carried on a general surveying practice in city and railroad work. The firm was dissolved in 1885, and Mr. Lyte acted for a year as the general western agent of the Morse Bridge Company. In 1888 he was chief engineer of the Kane Oil Field Railroad. From June, 1889, to June, 1891, he was general eastern agent for the Variety Iron Works Company, and afterward represented the Massillon Bridge Company in the East.

When the First National Bank at Kane, Pa., was organized, early in 1896, Mr. Lyte was unanimously chosen cashier, and he held this position until his death, which occurred on June 24th, 1896.

* Memoir prepared from information furnished by Dr. E. Oram Lyte, and from papers on file at the Society House.

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Vol. XXIII. OCTOBER, 1897. No. 8.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

SOCIETY AFFAIRS.

PAPERS.

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The prices of publications are as follows: Proceedings, $6 per annum; Transactions, $10 per annum. Postage will be added when they are sent to foreign countries.

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The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—127 EAST TWENTY-THIRD STREET, NEW YORK.

Vol. XXIII. OCTOBER, 1897. No. 8.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

October 6th, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 47 members and 9 visitors.

The minutes of the meetings of September 1st and 15th, 1897, were approved as printed in *Proceedings* for September, 1897.

The Chair appointed Messrs. Henry Goldmark, George Baum and M. E. Evans tellers to canvass the ballot on the proposed amendment of Article V, Section 1, of the Constitution.

The Secretary announced that the New Society House would be formally opened on November 24th, 1897.*

* See announcement, page 170.

A paper by J. P. Frizell, M. Am. Soc. C. E., entitled "Pressures Resulting from Changes of Velocity of Water in Pipes," was presented by the Secretary, who read correspondence on the subject from Messrs. J. P. Frizell, T. A. Noble and Charles W. Sherman. The paper was discussed by Messrs. Rudolph Hering and Henry Goldmark.

Ballots were canvassed and the following candidates declared elected:

As Members.

Gilbert James Bell, Keithsburg, Ill.
Abraham Lincoln Hyde, Cleveland, Ohio.
Edgar Marburg, Philadelphia, Pa.
David Albert Molitor, Detroit, Mich.
Thomas Laidlaw Raymond, New Orleans, La.
Maurice Augustus Vielé, Katonah, N. Y.

As Associate Members.

Emil Diebitsch, Brooklyn, N. Y.
William Willard Locke, Brooklyn, N. Y.
Walter Scott Winn, Florence, Ala.

The Secretary announced the election by the Board of Direction on October 5th, 1897, of the following candidates:

As Juniors:

Frederick Auryansen, Piermont, N. Y.
Theodore Belzner, New York City.
Richard Davenport Chase, Brooklyn, N. Y.
Curtis Hill, Carbondale, Ill.
Ned Herbert Janvrin, Steelton, Pa.

The Secretary read the list of nominees* presented by the Nominating Committee for the offices to be filled at the next annual election.

The report of the tellers appointed to canvass the ballot on the following proposed amendment to the Constitution was read by the Secretary:

Article V.—Officers.

1.—The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Secretary, and a Treasurer, who, with

* See page 169.

the five latest living Past-Presidents, who continue to be members, shall constitute the Board of Direction in which the government of the Society shall be vested, and who shall be the Trustees as provided for by the laws under which the Society is organized. For the election of Honorary Members, all the Past-Presidents shall be members of the Board of Direction, except any Past-President who may be disqualified by mental or bodily infirmity, and the evidence of said disqualification shall be a written certificate from his attending physician, or some officer of the Society.

REPORT OF TELLERS.

Vote on Amendment.

Total ballots received		494
Not entitled to vote	11	
Without signature	4	
Blank and irregular	5	
Voted and counted	474	
	—	494
Number of affirmative votes necessary for the adoption of an amendment (two-thirds of all ballots cast)		316
Yeas	427	
Nays	47	

Henry Goldmark,
George Baum,
M. E. Evans,
Tellers.

The Chair announced as the result of the canvass that the proposed amendment to Section 1 of Article V of the Constitution is adopted, two-thirds of all the ballots cast being in favor of this amendment.

Adjourned.

October 20th, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 57 members and 11 guests.

A paper by O. E. Selby, Jun. Am. Soc. C. E., entitled, "Painting the Louisville and Jeffersonville Bridge," was presented by the Secretary, and discussed by Messrs. Breithaupt, Purdon, Graves, A. H. Sabin, Goldmark, L. L. Buck, North, Purdy, M. E. Evans, A. McC. Parker, Whinery, Metcalf, John Thomson, Ira A. Shaler and R. W. Lesley.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

October 5th, 1897.—Nine members present.

The appointment was announced of the following members as a Board of Censors to award prizes for 1897: Frederic P. Stearns, Robert Moore, Henry B. Richardson.

A communication was received from the Nominating Committee nominating candidates for the offices to be filled at the next annual election.*

The resignation of John M. Goodell, Assoc. Am. Soc. C. E., as Assistant Secretary was presented and accepted.

T. J. McMinn, M. Am. Soc. C. E., was appointed Acting Assistant Secretary.

Applications were considered and other routine business transacted.

Five candidates were elected as Juniors.†

Adjourned.

EARTH SLOPES IN TROPICAL COUNTRIES.

An Informal Discussion at the Meeting Held September 1st, 1897.

L. M. Haupt, M. Am. Soc. C. E.—I have been giving some attention to the effects of exceptionally heavy rainfall upon earthwork, and I would like to ask any member of the Society who has had experience in tropical or subtropical countries, where the rainfall is unusually heavy, if he can give any data as to the stability of the slope, or the angle at which slopes of various material will resist the abrasive action of such rainfall. It is stated that in some places on one road I am now investigating there is a rainfall of over 300 ins. a year, and yet the slopes are $1\frac{1}{2}$ to 1 in embankments, and 2 to 1 in excavation, and stand remarkably well.

F. P. Davis, M. Am. Soc. C. E.—I have had an experience of several years in tropical countries, and think that slopes steeper than 1 to 1 will stand better than anything flatter. My first experience was in Nicaragua. I have seen slopes there where the material was a decomposed volcanic rock. It would ordinarily be classed as a very tough and tenacious clay. Those slopes, after they had been taken out three years, had worn so little that writing scratched on their face when they were taken out was still readable. The face of the slope had been

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* See page 169. † See page 164.

grown over very little with vegetation, but the natural surface of the ground, the right of way, was covered with a dense growth of grass, which would materially assist in preventing erosion. I have had also some experience in Costa Rica, where the railroad running from Port Limon to San José is a very steep mountain road all the way. The cuts are generally taken out steeper than 1 to 1, and stand better than when flatter. There are some places on the road where they have very bad landslides. Those are where the material is a volcanic ash mixed with a badly fractured shale. In time of very heavy rains this becomes saturated, and the whole side of the mountain slides, so that the railroad has frequently been blocked from one to six weeks. At other points, where the material is a clay, there is very little trouble with landslides. I have also noticed on the roads in Venezuela that most of their slopes are taken up much steeper than 1 to 1. They stand very well, and there is very little evidence of sliding. I have seen clay standing vertical in Nicaragua with a heavy stream of water pouring over it, and it has stood for years. The clay there, while it is hard apparently, in reality is not. It appears like a rock bottom, although a stick can be run into it.

Frank P. Lant, Jun. Am. Soc. C. E.—The earth embankments on the railway in Jamaica, British West Indies, have stood well at slopes greater than $1\frac{1}{2}$ to 1, and I think the fact is explained by the manner in which they were formed. The material to form the embankments was carried in boxes, containing about $\frac{1}{80}$ of a cubic yard, on the heads of men and women, and deposited as directed by the foreman. The constant tramping of these bare-footed men and women consolidated the material and had a most beneficial effect.

In the earth cuts on the highways I do not believe the government engineers paid very strict attention to the question of slopes, as I have seen, upon a main highway, cuts about 10 ft. deep where the sides were vertical. My observation of them extended over nearly two years, and they seemed to be unchanged in that time. They had probably been made many years before.

E. J. Chibas, Assoc. M. Am. Soc. C. E.—Judging from personal observations, I can say that steep slopes in tropical climates stand better than in this country. The heavy rains do not seem to affect them as much as we would naturally expect. In the nine miles of railroad built by the Caribbean Manganese Company from Nombre de Dios, in the Department of Panama, we made the slopes of the cuts in clay steeper than 1 to 1, and varying between $\frac{1}{2}$ to 1 and $\frac{3}{4}$ to 1. We had expected that there would have been many slides after the completion of the railroad, but we considered that it would be cheaper and more convenient to clear the slides than to remove all the material during construction. We found, however, that comparatively few slides took place, and most of the cuts have remained standing at a steeper

inclination than 1 to 1. The railroad was built in 1894. The rainfall during that year was 127 ins. at the coast, and about 150 ins. at the upper terminal of the railroad. This amount of rainfall is probably a little below the yearly average in that locality. Most of the heavy slides since the railroad was built have been confined to two cuts. In one of them it is plain that the sliding is due to the peculiar formation at the locality in question, as a thin layer of sandy clay could be traced along the sides of the cut. This material, being somewhat permeable, would allow the water to run partially through it and soften it in such a manner as to precipitate its fall into the cut, carrying with it at the same time a good portion of the mass of material above it.

The spontaneous growth of vegetation over the sides of the embankments and cuts has a tendency to add considerably to their stability.

In mountainous sections in the tropics the clearing on the upper side should be very wide, as large trees on a steep hillside, that look as if they would stand unmoved for many years, are easily undermined by the erosion caused by the heavy rains, and in their downward journey frequently cause more or less extended slides.

About three months ago, while engaged in professional work in the region of Darien, in the Department of Panama, I examined a ditch six miles long that had been built to provide water power for the Darien Gold Mining Company, and although the ditch was built along a steep hillside, and with slopes of $\frac{1}{2}$ to 1, and even steeper in some places, very little sliding had taken place. The ditch had been built for over a year, and its dimensions are 4 ft. wide at the top, 2 ft. 9 ins. at the bottom, and 3 ft. deep. Most of the material through which it has been cut is clay, probably resulting from the decomposition of metamorphic rocks.

In conclusion, I might state that while going through the works of the Panama Canal, a few weeks ago, I noticed many steep slopes in cuts that had been left unfinished when the work was stopped, about 8 years ago, and comparatively few slides had taken place.

Boyd Ehle, Assoc. M. Am. Soc. C. E.—The fact to be emphasized in regard to these earth slopes is that they can be safely and preferably made steeper than in countries where affected by frost action. Even though subject to torrential rainfall, the side ditches of the railway cuts kept remarkably clean. The steeper slopes were apparently less subject to wear when standing as nearly as possible to the vertical. The slopes of the deep railway cuts in clay were taken out nearly vertical, and stood very well, as left by the steam shovel, the trimmed slope being less than $\frac{1}{4}$ to 1. These cuts stand very satisfactorily. After a long time of neglect the side ditches have not filled, and that there is but little wear is proven by the pick marks of the laborers

being clear and sharp after more than three years, and this where the rainfall may be 9 ins. some days, and with an average of about 270 ins. per year. The scanty vegetation growing on these slopes affords them no protection.

Samuel Whinery, M. Am. Soc. C. E.—Embankments and excavations are subject to destruction in two ways, one by the sliding away of the material, landslides as they are called, and the other by erosion. It has been my experience that in land not subject to slides, the steeper the slope can be made, the less will the erosion be, and the same is true of embankments. The explanation is simple enough. The erosion of an embankment, for instance, bears a direct ratio to the amount of water which passes over it. The surface exposed to falling water on a steep bank is less than on a flat bank. The amount of water carried is consequently smaller with a steep bank, and the erosion is less. A great many who are present have no doubt seen very prominent illustrations of how often clay and sandy loam will stand at very steep slopes. The bluffs along the Ohio and Mississippi Rivers are monumental indications of the ability of that kind of material to stand almost vertical. There are many of those bluffs that have stood apparently for a century almost vertical for a height of 40, 50 or 60 ft., yet they are eroded so little by the water that moss and lichens are growing in the clay at some points. They have an appearance of age clearly indicating that they have not been eroded. I may say, further, that in excavations where clay is likely to slide, or where it is of a character that does slide, it has been my experience that flat slopes do not prevent it. In that kind of material, if the slope is made very flat, it absorbs more water, and, having absorbed water, it is in a condition to slide. It slides out in large pockets, and a peculiarity of all these pockets wherever they are observed is the fact that the rear is almost vertical. They begin sliding out with a vertical back and a horizontal face.

ANNOUNCEMENTS.

LIST OF NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 19th, 1898.

In accordance with Article VII, Section 2, of the Constitution, the Nominating Committee having presented to the Board of Direction a list of nominees for the offices to be filled at the next Annual Election, so chosen as to provide, with the officers holding over, a Vice-President and six Directors residing in District No. 1, and twelve Directors divided equally, with regard to number and residence, among the remaining districts, Nos. 2, 3, 4, 5, 6 and 7, and the Board, having

examined said list, now sends it, in accordance with Section 3 of the same article, to every Corporate Member of the Society.

For President, to serve one year.

ALPHONSE FTELEY, New York City.

For Vice-Presidents, to serve two years.

EDWARD P. NORTH, New York City, representing District No. 1.
FREDERIC P. STEARNS, Boston, Mass., representing District No. 3.

For Treasurer, to serve one year.

JOHN THOMSON, New York City, representing District No. 1.

For Directors, to serve three years.

S. L. F. DEYO, New York City, representing District No. 1.
JOHN KENNEDY, Montreal, Que., representing District No. 2.
HENRY MANLEY, Boston, Mass., representing District No. 3.
CHARLES C. SCHNEIDER, Pencoyd, Pa., representing District No. 4.
JOHN J. McVEAN, Grand Rapids, Mich., representing District No. 5.
GEORGE Y. WISNER, Detroit, Mich., representing District No. 5.

FORMAL OPENING OF NEW SOCIETY HOUSE,

No. 220 WEST 57th STREET.

The Board of Direction has appointed a Committee, consisting of the President, Secretary, Treasurer and the Chairmen of the Finance and Building Committees, to take charge of all the arrangements for the opening of the **New House** of the Society, and the following programme has been decided upon:

The date fixed for the formal opening is **Wednesday, November 24th, 1897**, and on this day the house will be open for inspection by members and their friends from 9 until 2 o'clock.

In the afternoon, beginning at 3.30, formal exercises will be held in the Auditorium. A programme for this meeting is now being arranged by the Committee.

In the evening at 9 o'clock there will be a House Warming, at which dancing may be expected and supper will be served.

The Committee has decided that the following rules must be enforced as to admissions:

All tickets must be obtained on application to the Secretary. Each Member may secure a card for himself and for two guests, either ladies or gentlemen, for the exercises in the afternoon, and cards for himself and one lady for the evening function. Additional cards may also be secured by members for other ladies of their immediate families. In all cases names of guests must be furnished, and cards will not be transferable.

MEETINGS.

Wednesday, November 3d, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Corydon T. Purdy, M. Am. Soc. C. E., entitled "Can Buildings be Made Fire-Proof?" will be presented. It was printed in the September number of *Proceedings*.

Wednesday, November 17th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by James C. Branner, Ph. D., entitled "Geology in Its Relations to Topography" will be presented. It is printed in this number of *Proceedings*.

Wednesday, December 1st, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by William Cain, M. Am. Soc. C. E., entitled "Theory of the Ideal Column," will be presented. It is printed in this number of *Proceedings*.

DISCUSSIONS.

Discussion on the paper by J. L. Van Ornum, Assoc. M. Am. Soc. C. E., entitled "Theory and Practice of Special Assessments," which was presented at the meeting of September 15th, 1897, will be closed November 1st, 1897.

Discussion on the paper by J. P. Frizell, M. Am. Soc. C. E., entitled "Pressures Resulting from Changes of Velocity of Water in Pipes," which was presented at the meeting of October 6th, 1897, will be closed November 15th, 1897.

Discussion on the paper by O. E. Selby, Jun. Am. Soc. C. E., entitled "Painting the Louisville and Jeffersonville Bridge," which was presented at the meeting of October 20th, 1897, will be closed December 1st, 1897.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Name	Address	Grade	Date of Membership.
HYDE, ABRAHAM LINCOLN	816 New England Bldg., Cleveland, Ohio	Assoc.M. M.	April 4, 1893 Oct. 6, 1897
McNICOL, JOHN ALEXANDER	Providence, R. I.		Sept. 1, 1897
MARBURG, EDGAR	Professor of Civil Engineering, University of Pennsylvania, Philadelphia, Pa.		Oct. 6, 1897
MOLITOR, DAVID ALBERT	U. S. Asst. Engr., 41 Telephone Bldg., Detroit, Mich.		Oct. 6, 1897
SJÖSTRÖM, IVAR LUDWIG	Lawrence, Mass.	Jun. M.	Sept. 6, 1892 Sept. 1, 1897
VIELÉ, MAURICE AUGUSTUS	Katonah, N.Y.	Jun. Assoc. M. M.	Feb. 4, 1891 Sept. 7, 1892 Oct. 6, 1897

ASSOCIATE MEMBERS.

Name	Address	Date of Membership.
SPALDING, WILLIAM AARON	City Engineer, Waxahachie, Tex.	Apr. 7, 1897
WRIGHT, JOSEPH BODINE	465 West 22d St., New York City	June 2, 1897

ASSOCIATE.

Name	Address	Date of Membership.
NORTON, HENRY LORD	Collins & Norton, Engineers and Contractors, Mason Bldg., 33 Lyman St., Springfield, Mass.	May 4, 1897

JUNIORS.

Name	Address	Date of Membership.
CLARK, JOHN A., Jr.	East River Gas Co., 138 West 42d St., New York City	Aug. 31, 1897
HORTON, THEODORE	Metropolitan Sewerage Commission, 1 Mt. Vernon St., Boston, Mass.	Aug. 31, 1897
JANVRIN, NED HERBERT	Care of Pennsylvania Steel Co., Steelton, Pa.	Oct. 5, 1897

CHANGES AND CORRECTIONS.

MEMBERS.

ABBOT, FREDERIC VAUGHAN .... Capt. Corps of Engrs., U. S. A., U. S. Engr.'s Office, Dept. of Dakota, St. Paul, Minn.

BALDWIN, FRED HIXON .... Asst. Supt. Bergenport Chemical Works, P. O. Box 230, Bayonne, N. J.

BIXBY, WILLIAM HERBERT .... Maj. Corps of Engrs. U. S. A., Custom House, Cincinnati, Ohio.

COLLINGWOOD, FRANCIS .... Elizabeth, N. J.

DAVIS, ROBERT BENJAMIN .... Prin. Asst. Engr., Brooklyn Elev. R. R. Co., 31 Sands St., Brooklyn, N. Y.

DAVIS, FRANK PAUL .... Care of Nicaragua Canal Comm., Army Bldg., N. Y. City.

ERLANDSEN, OSCAR .... 431 Fulton St , Jamaica, N. Y.

FILLEY, HIEL HAMILTON .... 2d Avenida Juarez No. 4, City of Mexico, Mexico.

FOLLETT, WILLIAM W .... El Paso, Texas.

FOX, STEPHENSON WATERS .... Div. Engr., Missouri River Comm., Jefferson City, Mo.

FRYE, ALBERT IRWIN .... 155 West Canton St., Boston, Mass.

HEUER, WILLIAM HENRY .... Maj. Corps of Engrs., U. S. A., 59 Flood Bldg., San Francisco, Cal.

HOWE, WILLIAM BELL WHITE .... Kingsford, Fla.

HUDSON, JOHN ROGERS .... 199 South Canal St., Chicago, Ill.

HUMPHREYS, ALEXANDER CROMBIE ..... 31 Nassau St., New York City.

McMINN, THOMAS JAMES .... 127 East 23d St., New York City.

MILLER, ALEXANDER MACOMB .... Maj. Corps of Engrs., U. S. A., Army Bldg., New York City.

ODELL, FREDERICK SYLVESTER .... Black Mountain, N. C.

PURDY, CORYDON TYLER .... 78 Fifth Ave., New York City.

RIFFLE, FRANKLIN .... 15 Broad St., Victoria, B. C.

SCHAUB, JULIUS WILLIAM .... Care of Arc Welding Co., 24 Newberry Bldg., Detroit, Mich.

SIMS, ALFRED VARLEY .... Iowa City, Iowa.

SLOAN, ROBERT INSLEY .... 209 West 87th St., New York City.

WOOD, HENRY BEECHER .... Chf. Engr., Mass. Topographical Survey Commission, 11 Mt. Vernon St., Boston, Mass.

ASSOCIATE MEMBERS.

FOLWELL, AMORY PRESCOTT .... Sanitary and Hydraulic Engr., Easton, Pa.

FORT, EDWIN JOHN .... 79 Hanson Place, Brooklyn, N. Y.

FOYÉ, ANDREW ERNEST .... Member of firm Foster & Foyé, 11 Broadway, New York City.

GRAY, WILLIAM .... Asst. Engr., Croton Aqueduct Comm., Bronxwood Park, Williamsbridge, New York City.

HILL, JOHN EDWARD .... Brown University, Providence, R. I.
LYONS, JAMES KNOX .... 214 Mathilda St., Pittsburg, Pa.
MILLER, HEW .... 71 Pineapple St., Brooklyn, N. Y.
ROSENBERG, FRIEDRICH .... 136 State St., Albany, N. Y.
SMITH, JONAS WALDO .... 107 Washington St., Paterson, N. J.
ULRICH, DANIEL .... 269 West 136th St., New York City.
VORCE, CLARENCE BROWNING .... 103 Ballerstein Bldg., Hartford, Conn.
WALKER, JOHN SHAW .... Resident Engineer's Office, Existing Lines West Australian Government Rys., Perth, West Australia.
WHEATLEY, ARTHUR CORNWALLIS .... Chf. Engr. Léon Somzée y Cia., Mazapil, Zacatecas, Mexico.
WOERMANN, JOHN WILLIAM .... Sheffield, Ill.

ASSOCIATE.

HUNSIKER, MILLARD .... 47 Victoria St., Westminster, London, England.

JUNIORS.

BELL, GILBERT JAMES .... 350 La Salle Ave., Chicago, Ill.
BURDEN, MORTON .... 5943 Alder St., Pittsburg, Pa.
COULSON, BENJAMIN LE FEVRE .... Care of Foster & Foyé, Room 1167, 11 Broadway, New York City.
FORD, WILLIAM HAYDEN .... 143 Lexington Ave., New York City.
GREEN, RUTGER BLEECKER .... 706 East Fayette St., Syracuse, N. Y.
JACKSON, WILLIAM .... 440 Atlantic Ave., Pittsburg, Pa.
McCORMICK, GEORGE KING .... Hazlepatch, Laurel Co., Ky.
MAGOR, HENRY BASIL .... 103 So. Oxford St., Brooklyn, N. Y.
MEYER, HENRY CODDINGTON, Jr. .... 100 William St., New York City.
RICHARDS, JERRE TURNER .... 406 Locust St., Philadelphia, Pa.
RUSSELL, RICHARD LORD .... 478 State St., Brooklyn, N. Y.
RYDER, ELY MORGAN TALCOTT .... 101 West Divinity Hall, New Haven, Conn.
SWINDELLS, JOSEPH SPRINGER .... 15 Linn St., Ithaca, N. Y.
THOMPSON, ROBERT ANDREW .... Instructor of Applied Mathematics, University of Texas, Austin, Texas.
TODD, ALEXANDER MILLER .... U. S. Inspector, Shiloh, Miss.
WILKINS, GEORGE SHREVE .... University of Alabama, Tuscaloosa, Ala.
WILSON, CHARLES WILLIAM SCHRAGE ... New Rochelle, N. Y.

DEATHS.

LAWTON, FREDERICK BEECHER .... Elected Junior Nov. 5th, 1891; Assoc. M. Nov. 4th, 1896; died Oct. 13th, 1897.
MANN, GEORGE EDWARD .... Elected Member Sept. 3d, 1884; died Oct. 2d, 1897.

ADDITIONS TO

LIBRARY AND MUSEUM.

From American Institute of Mining Engineers, New York City:
 Officers, Members, Rules, etc., August, 1897.
 Proceedings of the 73d Meeting, Lake Superior, July, 1897; Methods of Iron Mining in Northern Minnesota; Biographical Notice of George W. Goetz; Potsdam Gold Ores of the Black Hills of S. Dak.; Influence of Lead on Rolled and Drawn Brass; Fullers' Earth of S. Dak.; Clays and Clay-Working Industry of Colorado; Electrolytic Assay as Applied to Refined Copper; Development of Lake Superior Iron Ores; Combination Retort and Reverberatory Furnace; Chicago Main Drainage Canal; Notes on the Tin Deposits of Mexico; A Mine Dam; Some Dike Features of the Gogebic Iron Range; The Cyanide Process; Microstructure of Steel and the Current Theories of Hardening; Cement Deposits of Arkansas.

From L'Association Amicale des Anciens Eleves de l'Ecole Central des Arts et Manufactures:
 Bulletin of the Association for August, 1897.

From L'Association des Ingénieurs sortis des Écoles Spéciales de Gand:
 Annales of the Association. Tome XX, 1896-97. Troisième Livraison.

From Board of Trustees, Sanitary District of Chicago:
 Proceedings for August 4th, 11th and 25th, 1897.

From California Academy of Sciences, San Francisco, Cal.:
 The Submerged Valleys of the Coast of California, U. S. A., and of Lower California, Mexico.
 The Reptiles of the Pacific Coast and Great Basin. By John Van Denburgh.

From Canadian Society of Civil Engineers, Montreal, Can.:
 Transactions, Vol. X, Part II.

From the Citizens' Municipal Association of Philadelphia:
 Eleventh Annual Report of the Association, with list of Members, Officers and Committees for 1897.

From the Commissioner of Education, Washington, D. C.:
 Report of the Commissioner of Education for the Year 1895-1896. Volume I, containing Part I.

From General J. S. Fullerton, U. S. A., Chairman of the Chickamauga and Chattanooga National Park Commission, Washington, D. C.:
 Atlas of the Battlefields of Chickamauga, Chattanooga and Vicinity, VII Plates.

From the C. W. Hunt Co.:
 Coal Handling for Steam Generation.

From Institution of Civil Engineers, London, Eng.:
 List of Members, September, 1897.

From J. Francis LeBaron:
 Monthly Bulletin of the Bureau of American Republics.

From Liverpool Engineering Society:
 Transactions, Vol. XVIII, 23d Session, 1897.

From Master Car-Builders' Association:
 Proceedings, Vol. XXXI, 1897.

From McGill University, Montreal, Que.:
 The Annual Calendar for 1897-98, with Examination Papers.

From Michigan College of Mines, Houghton, Mich.:
 Prospectus for 1897-98.

From Minister of Railways for New South Wales:
 Annual Report of the Railway Commissioners of Government Railways and Tramways for the year ending 30th June, 1897.

From A. C. Mountain, Melbourne, Australia:
 Wood-Paving in Australia.

From the North-East Coast Institution of Engineers and Shipbuilders:
 Transactions, Vol. XIII, 1896-97.

From the New York Central and Hudson River Railroad Company:
 Twenty-eighth Annual Report of the Board of Directors for the year ended June 30th, 1897.

From Herman Poole, New York City:
 Bulletin de la Commission Internationale du Congrès des Chemins de Fer. Vol. I, Nos. 9, 10, 11; Vol. II, Nos. 3, 5, 6, 8, 10, 11, 12; Vol. III, Nos. 1, 2, 3, 4; Vol. IV, Nos. 9, 10, 11; Vol. V, Nos. 1-2, 3, 4-5-6, 7-8-9, 10, 12; Vol. VI, Nos. 1, 2, 3, 4, 5, 7, 8; Vol. VII, Nos. 7*a*, 9, 10; Vol. VIII, Nos. 8, 12; Vol. IX, Nos. 1, 5, 7.
 Bridge Building, by S. Whipple.

From Royal Institution of Engineers, The Hague, Netherlands:
 Gedenkboek uitgegeven ter Gelegenheid van het Vijftigjarig Bestaan van het Koninklijk Instituut van Ingenieurs, 1847-97.

From Royal Society of Canada:
 Proceedings and Transactions. Second Series, Vol. II, 1896.

From Secretary of the Interior, Washington, D. C.:
 Report on Population of the United States at the Eleventh Census, 1890, Part II.

From U. S. War Department:
 Survey of Buffalo Entrance to Erie Basin and Black Rock Harbor, New York (in duplicate).
 Survey of Tampa Bay, Florida (in duplicate).

Survey of Erie Harbor (in duplicate).
Survey of New Haven Harbor, Connecticut (in duplicate).

From U. S. War Department, Chief of Engineers:
Twenty-three Specifications for Dredging; Levee Construction; River Improvement; Harbor Work; Wharves; Dams; Wreck Removal; Retaining Wall; Supply of Cement, Stone, Castings, Steel, Electric Lighting Plant, etc., etc.
Sixteen Specifications of River, Canal and Harbor Works, Gun Emplacements, Piers, Barges, Materials, etc., etc.
Specifications and Two Blue-Prints for the Breakwater at Presque-Isle Point, Marquette, Mich.
Specifications and Seven Blue-Prints for Two Breakwater Piers at Lake Superior Entrance to Portage Lake Ship Canals, Mich.

From the War Department, U. S. A., Chief of Ordnance:
Annual Report of the Chief of Ordnance for the year ended June 30th, 1896.

From U. S. Geological Survey:
Seventeenth Annual Report, 1895-96, Parts 1, 2, 3, and 3 continued.
Monograph XXV: The Glacial Lake Agassiz, Upham.
Monograph XXVI: The Flora of the Amboy Clays, Newberry.
Monograph XXVII: Geology of the Denver Basin in Colorado, Emmons, Cross, Eldridge.
Monograph XXVIII: The Marquette Iron-Bearing District of Michigan, Van Hise, Bayley, Smith.
Atlas to Accompany Monograph XXVIII on the Marquette Iron-Bearing District of Michigan.
Bulletins, Nos. 87, 127, 130, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148. Synopsis of American Fossil Brachiopoda, including Bibliography and Synonym; Catalogue and Index of Contributions to American Geology, 1732-1891; Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy, for 1892-1893; The same for 1894; The Ancient Volcanic Rocks of South Mountain, Pennsylvania; The Geology of the Fort Riley Military Reservation and Vicinity, Kansas; Artesian Well Prospects in the Atlantic Coastal Plain Region; Geology of the Castle Mountain Mining District, Montana; Report of Progress of the Division of Hydrography for the Calendar year 1895; The Eocene Deposits of the Middle Atlantic Slope in Delaware, Maryland and Virginia; A Brief Contribution to the Geology and Paleontology of Northwestern Louisiana; Bibliography of Clays and the Ceramic Arts; The Moraines of the Missouri Coteau and their Attendant Deposits; The Potomac Formation in Virginia; Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy for 1895; Earthquakes in California in 1895; Analyses of Rocks and Analytical Methods, U. S. Geological Survey, 1880-1896.

From Royal Society of New South Wales:
Journal and Proceedings of the Society, Vol. XXX, 1896.

From Thomas B. Stillman:
The Action of Nitric Acid upon Aluminum and the Formation of Aluminum Nitrate.

From The Technical Society of the Pacific Coast:
Transactions of the Society, July, 1895, to December, 1896.

From John C. Trautwine, Jr., Chief of Bureau of Water, Philadelphia, Pa.:
Second Annual Message of Charles F. Warwick, Mayor of the City of Philadelphia, with Annual Report of Thomas M. Thompson, Director of the Department of Public Works, and of the Bureau of Water, for the year ending December 31st, 1896.

From University of the State of New York:
Report of Public Libraries Division, 1896.

From Horace G. Wadlin, Chief of Bureau of Statistics of Labor, Massachusetts:
Annual Statistics of Manufactures, 1896, Eleventh Report.
Twenty-seventh Annual Report of the Bureau of Statistics of Labor (Massachusetts), March, 1897.

From George T. Walch, Chief Engineer for Irrigation, Madras, India:
The Engineering Works of the Gódávari Delta. Vol. II.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS:

GEOLOGY IN ITS RELATIONS TO TOPOGRAPHY.

By JOHN C. BRANNER, Ph. D.*

TO BE PRESENTED NOVEMBER 17TH, 1897.

If there are laws governing the origin and development of topographic forms, nothing is clearer than that a knowledge of these laws must be of great importance to those who have to deal with such forms; and, indeed, there is a constant demand, among those who have not devoted much time to a study of the subject, for short and simple empirical rules for topography. There are such rules for topographic forms, but they hold good only in limited areas, and fail utterly whenever their general application is attempted. There is also a widespread disposition to appeal for explanation, especially of bold topographic forms, to the supernatural, to violent cataclysmic disturbances, subterranean upheavals, volcanic outbursts and "blow-outs," and to the Miltonian idea, in which: "The mountains huge appear emergent, and their broad, bare rocks upheave into the clouds." One serious-minded

* Professor of Geology in Stanford University.

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

writer thinks the great gorge in the Cascade Mountains, through which the Columbia River flows, was made by God drawing his finger across that range.*

To arrive at any comprehension of topography, such ideas must be put aside at the outset; and the laws that mould topography to-day, the agencies which produce it, the materials worked upon, and how the work is done, must be studied before the results can be understood.

Topography is the expression of geologic structure pretty much as the outlines of the human body are the expression of its anatomical structure. To be more precise, topography is the resultant of the operations or eroding agencies and the resistance of the rocks, the time of their exposure, the initial position of the surface, and the orographic changes suffered. These are all fundamentally matters of geology, and the following generalizations may be laid down without fear of successful contradiction: first, that no one can understand topography unless he comprehends the geologic reasons for it; and secondly, that unless one understands topography he cannot represent it correctly. To set a man at work on topography who knows nothing of geology is very like having some one perform a surgical operation who knows nothing of anatomy.

"We see, according to the light that is within us." One cannot picture a subject he has not studied. However skilled a draftsman or artist may be in the technique of his art, unless he understands the animal or plant he has to draw, he cannot make a correct picture of it. In topographic representation this is equally true, and it is the more important because a large part of every map must be sketched in, and this sketching cannot be done properly unless he who does it knows what ought to be there. Unless the topographer knows what to look for he doesn't find it, or he finds only a part of it. This statement is based on no small amount of experience of this fact. It has been the author's duty to employ many topographers, and all his experience of their work has but confirmed this opinion.

It is of the utmost importance to the topographer that he should know what kind of topography to expect, and, to this end, the more he knows of the materials in which topography is cast, and of the agencies that shape it, the clearer will be his insight, the less waste of time

* Journal of an exploring tour beyond the Rocky Mountains, by Rev. Samuel Parker, Ithaca, N. Y., 1838, p. 215.

and energy will there be, and the truer will be his representation of the relief.

The object of this paper is partly to point out the origin and controlling factors of some of the more important topographic forms, and partly to show the necessity of a knowledge of geology—especially of structural geology to the topographer.

Rocks the Material of Topography.

Topography as here dealt with is the representation of the forms of the earth's surface. These forms are impressed upon, carved in, or otherwise made of the soils and rocks of the earth's crust; but these rocks vary among themselves to such an extent, in hardness, structure, texture and position, that when subjected to the same shaping agencies they yield very different results. It is necessary, therefore, at the outset, that the topographer should have at least a general knowledge of the different kinds of rocks, what they are, how they originate, and of the forms of the masses in which they occur.

For the purposes of the present paper rocks may be classified according to the forms and origin of their beds as follows:

Water-bedded rocks or those laid down in water as mechanical, chemical or organic sediments.

Wind-bedded rocks, or those deposited on land in the form of blown sand or dust.

Organic deposits, or those made by living organisms, whether animal or plant.

Igneous rocks, or those cooled from a molten condition.

Origin of the Different Kinds of Rocks.

Brief descriptions of the methods of formation of these different classes of rocks will be given in order that the forms of the deposits may be understood, and eventually the topographic relief to which they give rise.

The Origin of Water-Bedded Rocks.—Water-bedded or sedimentary rocks are those made of sediments, or fragmental, or skeletal materials, whether of mineral or organic origin, and laid down in water.

The sands, gravels, and clays washed by a stream into a lake or sea settle to the bottom and form beds of mechanical sediments. In time

the sands form sandstones, the gravels make grits and conglomerates, and the clays make shales and slates. When the microscopic organisms that live in the sea perish, their skeletons sink to the bottom and form beds of organic origin. Waves beat upon shores strewn with molluscan shells or upon coral reefs, break off fragments and grind them to powder, and this material is swept out by the undertow and sinks to the bottom to form sedimentary beds of organic origin. All these sedimentary deposits, whether they are coarse heavy cobblestones, small pebbles, sands or clays, are deposited in approximately horizontal layers in the bottom of the lake, sea, or ocean.

It is important to note also that the marine sediments are either carried down from the land by streams, or are taken from the immediate shores and carried out to sea by the undertow. It follows in either case that the heaviest sediments, the boulders and pebbles, sink to the bottom first and nearest the shore, while the finest silts, the clays, are carried farthest. The currents bearing the finer silts seaward are seldom checked suddenly, and the result is that the weight of the particles which can be carried in suspension decreases with the force of the current. For this reason, over any given area, the coarser sediments merge imperceptibly into the finer ones.

When, in the course of the earth's history, such beds are lifted from the sea bottom to form land, the peculiarities and local variations of these deposits must have some influence on the topography carved in them.

In the case of marine sedimentary beds, made up wholly or largely of the skeletal remains of microscopic organisms, the deposits are not so liable to local variations as are the mechanical silts. These marine organisms live in the water at or near the surface, and their remains sink to the bottom over large areas, while the uniformity in their sizes and weights offers but little opportunity for any selective action by currents.

Some water-laid beds are produced by chemical precipitation. In the case of salt lakes, where the water is being evaporated, when it reaches a certain density, the gypsum in solution is precipitated, and further evaporation causes the precipitation of the salt. The beds thus deposited settle over and conform to the bottom of the basin, and are therefore, in form, very like mechanically deposited sediments.

Wind-deposited rocks will not be discussed in this paper.

Organic deposits, other than those already mentioned, are coral reefs and peat beds. The coral reefs produce some of our limestone beds, while lignite and coal have been formed from peat. The coral reef rocks are the skeletons secreted by coral polyps. The reef-building forms of these animals can live only in warm (68° Fahr.), shallow (less than 100 ft.) sea water, and they are thus obliged to extend their beds horizontally, except where by slow subsidence of the sea bottom they are enabled to grow upward.

Peat grows only in moist places, and for the most part in flat, marshy ones, such as the Dismal Swamp of Virginia. In the course of geologic time the peat becomes lignite, and still later coal. The interstratification of coal beds with marine sediments can only be accounted for by supposing the peat beds to have sunk beneath the sea, and that subsequent elevation permitted the re-establishment of the peat swamps.

Igneous Rocks.—The rocks that have been in a molten condition include the masses that have been poured out through the crust and over it as great lava outflows, those that have filled and cooled in cracks in other rocks, and also the materials that have been blown out by volcanoes and have fallen to the earth as ashes and scoriæ. Where these rocks have been spread over the surface as lava sheets, their forms have been determined by the fluidity of the molten rock and by the surface over which they have spread. Sometimes they have been submerged after cooling, and sedimentary beds have been laid down on top of them. Where they have been intruded into crevices, their forms have been fixed by the crevices themselves. These are known as dikes. In the cases of fragmental materials blown from volcanic vents, the forms are limited to local accumulations lying in conical heaps. Sometimes these materials have fallen in water, and, settling to the bottom, have taken on the appearance of sedimentary beds, so far, at least, as their gross structure is concerned. Such beds are known as water-laid tuffs.

The Internal Changes Suffered by Rocks.

The materials of sedimentary rocks are at first soft and incoherent, but in the course of geologic time most of them become compact and hard, either from the pressure of other rocks heaped upon them, on account of the deposition within them of cementing materials or from

a combination of the two, or on account of metamorphism or internal changes.

Angular rock fragments form breccias, pebbles and gravels; other coarse sediments form conglomerates, or pudding stones; sands form sandstones, and clays form shales or slates. The calcareous organic remains form chalks and limestones, while siliceous organisms make diatomaceous earths, cherts, flints and jaspers. Peats form lignite and coal. Even the igneous rocks themselves are often greatly changed by being reheated or by the action of hot water. These changes are all internal; some of them are the results of physical forces, such as pressure, while others are of a chemical nature.

Structural Changes in Beds of Rocks.

Although the sedimentary rocks were originally laid down in approximately horizontal beds, yet, where they have been lifted from beneath the water, they have not always risen evenly. Their horizontality has been disturbed. They have been tilted this way and that, sometimes thrown into gigantic folds miles across, sometimes into wrinkles or close crumples, and sometimes they are broken, and the edges of the beds have slipped past each other. These last-mentioned breaks and displacements are called faults.

Folds and faults are likely to occur in groups, that is, gentle folds occur together, and closely squeezed folds occur together, but the two kinds are not often found in the same region. Folds may be long or short. Short folds often overlap each other slightly at the ends. The axes of folds are generally approximately parallel in a given area.

Faults are also disposed to parallel systems in a given region. They may be close together or far apart; and the amount of displacement may be anywhere between a fraction of an inch and thousands of feet.

It is of the utmost importance to the topographer that he should understand these folds and faults, for they frequently have a great influence upon the topography. Regarding the size, character or relations of folds and faults, there is no general law that can be laid down in anticipation of what may be found in any new region. Their distribution is seldom to be anticipated, but must be determined by a study of the outcrops. A knowledge of the methods of determining and locating these structural features is indispensable.

Topographic Relief.

If a lava stream emerges from beneath the earth's surface and spreads out over a wide area, it will, if a very fluid lava, form a flat surface by filling up the existing irregularities, much as if the region had been submerged by water and the water had frozen. If a volcano should burst forth upon a plain and should eject large quantities of pumice, scoriæ, ashes, and the like, these materials would accumulate about the mouth of the vent and build up a volcanic cone. In both instances the topography would be formed by direct construction.

If a part of the ocean's bottom should be uncovered or brought up and left as dry land, it would be found that this new surface had certain irregularities; but rain and frost and streams would soon begin to attack it, to cut stream beds in it and to produce topographic forms altogether different from its original surface. The new shore line, at first comparatively smooth, would at once be attacked by the waves, and a steep-faced bluff would mark the new beach. All this cutting and shaping of the new topography would be the work of removing or of destructive agencies.

These two general classes or agencies—the constructive and destructive—produce most of our topographic forms. They will be considered in this order.

Constructive Agencies and the Forms They Produce.

Subaqueous Forms.—Constructive topographic agencies, in the broad sense, should include subaqueous constructive forms; but while the forms of delta deposits and off-shore accumulations generally are constructive forms, they are of comparatively little importance, because after emergence they are soon obliterated. There are well-known instances, however, of such forms, and for that reason they will be briefly described.

When a stream carrying silts enters a quiet body of water, the checking of the current causes some of the silts to fall to the bottom. In fresh waters some of the finest particles remain for a long time suspended in the water, but the salts in salt water cause these fine particles to flocculate or cling together in little bunches and thus hasten their sinking to the bottom. Wherever a muddy stream enters a lake or sea the silts it bears fall to the bottom about the stream's mouth,

and, in time, build up deltas such as are found about the mouths of the Nile, the Rhône and the Mississippi.

These deltas, through the operation of floods, build up so as to rise above the average water surface. They are flat on top, while their seaward faces may slope off more or less rapidly into deep water. In outline they tend to be fan shaped. Wherever there has been an elevation of a delta deposit above water, the form has been found like that here described. The Great Salt Lake in Utah not long ago covered an area of 19 750 square miles, and the streams flowing into it made deltas, which, by the drying up of the water, have been left uncovered. Wherever the waves of that lake beat upon its shores, accumulations of considerable size and extent were formed. These deposits are now part of the surface relief of the region.

Spits and Bars.—Bars are formed about the mouths of streams by conflicting currents. When a stream enters the ocean its current tends to sweep the sands it bears out into deep water; but when the tide comes in, the current is reversed and flows up the channel of the stream, and these sands are carried in the opposite direction. The sands tend to accumulate on some middle ground where the currents balance each other, and here they build up a bar which, by the help of storm waves and high tides, may rise above the water. Sometimes conditions may favor the accumulation of these silts on one side of a stream's mouth rather than the other, and they may stretch across it, forming a spit.

Waves do not always break squarely against the shore, but more frequently the surf runs along the beach according to the angle of the wind with the shore. In some parts of the world the winds blow so constantly from one direction that the sands are always carried one way. When there is an obstruction on such a beach an eddy is formed behind it, and here the waves leave the sands they sweep along, and, in time, a long spit or neck is built, commonly hooked at the outer end.*

Emergent Forms.—Emergent forms of topography are those built up partly beneath the water, but gradually rising above it. Deltas built into dry land, lakes filled up with silts, turned into marshes, and later into dry land, are examples of this kind. Sometimes the fiords

* For a comprehensive discussion of the topographic features of shores see "Lake Bonneville." By G. K. Gilbert, Monograph I. U. S. Geol. Survey.

or submerged valleys along sea coasts have spits and bars formed across their mouths by the waves and the currents of the open sea, while in the quiet waters behind them the silts brought down by the streams are deposited until these bays are turned into marshes and then into dry land. In such cases there is an older and more precipitous topography diving beneath a new and nearly flat surface. The swamps near Oceanside, California, were made in this manner.

Storm beaches and coral islands rising above the surface of the sea are also constructive emergent forms of topography. River terraces are produced partly by the constructive and partly by the destructive work of streams. Stream valleys are filled with silts and débris at times of floods, and when the streams shrink they cut their channels down through these materials, and in shifting from side to side leave terraces along their courses.

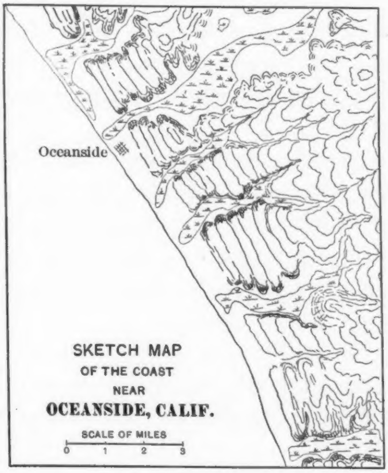

FIG. 1.

Subaerial Forms.—Subaerial forms produced by direct construction consist of volcanic ejectments and certain spring and geyser deposits. The surface forms assumed by lava depend upon the fluidity of the lava and upon the character of the topography over which it is spread. In the case of very fluid lavas the angle of the slope built up is quite low, while those less fluid stand at higher angles, or even bunch up in steep-sided heaps at no great distance from their vents.

The basaltic lavas are of comparatively easy fusibility, while the trachitic lavas are of difficult fusibility. Consequently, basaltic lavas form flat sheets or lava cones of low slopes, while the trachites, emerging in an almost pasty condition, are disposed to form steep-sided cones. Part of these differences, however, is due to the difference in the sizes of the outflows.

The profile of the great volcanic mountain, Mauna Loa, Hawaii, has so low an angle, from 4° to 6°, that it hardly impresses a person

climbing it as a volcanic mountain. Some volcanic cones are made up largely of loose ashes, scoriæ or broken bits of rock that have been thrown into the air by subterranean explosions, and, falling near the vents, have piled up as cones of débris that stand at the normal angle of repose, which is from 33 to 40 degrees. The lavas of Mauna Loa are basaltic; those of Mount Vesuvius are also basalts very little different from those of Mauna Loa, but Mount Vesuvius is made up largely of scoriæ and ashes, while Mauna Loa is chiefly of fluid lava.

These general laws will give some idea of the methods by which such features are formed originally, and of the topography to be expected about active volcanoes. It must not be forgotten, however, that there are over the earth's surface a great many extinct volcanoes, and while these may still retain much of their primitive forms, they are more frequently than otherwise so modified by eroding agencies that their characteristic outlines have become partly or entirely obliterated.

One peculiarity of the erosion of cinder cones is worthy of note in this place: the loose materials on the slopes of such peaks allow the water falling upon them to sink beneath the surface at once. In this way these peaks avoid much surface erosion, but the water issues as springs about the bases of the mountains, and their erosion cuts backward into the cones.

Spring Deposits.—These are formed by the precipitation from solution of the mineral matter brought to the surface by subterranean waters. They are of local importance only and are omitted from this discussion.

Faults and Folds.—In a sense those forces which produce folds and displacements of the rocks may be looked upon as constructive. We may have, for example, fault escarpments, or freshly made folds producing very marked topography. Such cases, however, are not so common as one might suppose, for the reason that the original outlines of features made in this way are soon modified by erosion to such an extent that they are thoroughly obscured or even entirely obliterated.

In the case, too, of both faults and folds the displacements often take place so slowly that erosion keeps pace with the movements, and the structural features produced by them never appear as marked topographic forms. In some cases, however, faults have produced marked topography. In most faulting there is a crack or break in the rocks,

and on one side of this break the edges of the fractured rocks are lifted above their former position, thus forming a step-like bluff. This escarpment may be from a few inches to several hundred feet high, and may be many miles in length. Such breaks are seldom straight, but have rough and more or less irregular edges, so that in detail a bluff produced by a fault is likely to be irregularly serrate or zig-zag in direction, although its general course may be approximately straight.

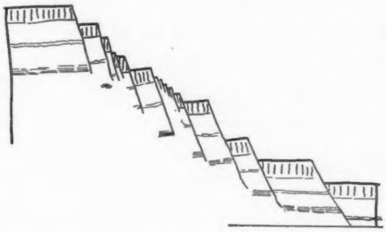

FIG. 2.

The surface forms that may be produced by faulting are almost as many as the forms of the fractures, depending upon the character and position of the rocks, the character of the force producing the faults, and the inclination of the fault face to the earth's surface.

FIG. 3.

Figs. 2, 3, 4 and 5 represent ideal vertical sections through the earth's crust. The upper surface in each case represents the surface of the ground. In Figs. 2 and 3 the faults have been produced by tension, while in Figs. 3 and 4, they have been produced by pressure. These faults may be close together or far apart, single or double, or they may branch out in different directions. While faults are not confined to any particular area or rocks, they are much more abundant in some regions than in others, while in some they may be entirely wanting. In a given region faults often show a decided tendency to occur in parallel sets, and these may cross each other at rather constant angles. In the Coast Ranges of California, for example, the faults are for the most part parallel to the coast line and the main axes of the mountains (see Plate XXV).

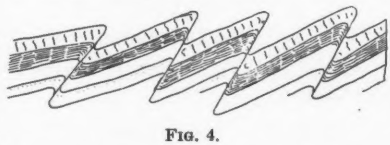

FIG. 4.

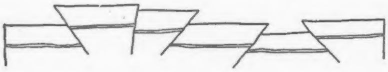

FIG. 5.

The original folds of surface rocks have, as a rule, been so long exposed that their primitive forms have been entirely destroyed. The

long, narrow valleys of California, running parallel with the coast and with the Sierras, were produced originally by faults, but they have been greatly modified and widened by stream erosion. As in the case of faults, the folding of rocks has taken place so slowly that erosion has been able to remove obstructions as rapidly as they rose across the drainage. Even in cases of anticlinal ridges, there have almost invariably been thick overlying beds removed from them. The characters of folds will be discussed under the head of topography of "folded rocks."

Destructive Agencies and How They Operate.

Eroding Agencies.—Most topography is cut in the rocks of the earth's crust. All rocks exposed over the earth, whatever their origin, are subject to the action of those natural agencies that cut out topographic forms. These agencies act with such extreme slowness that it is not an easy matter to realize their importance, or even to believe that such vast results can be produced by such apparently trifling forces. If, however, one can realize something of the immense periods of time during which these agencies have been at work, there will be no difficulty in comprehending the results.

The agencies that attack, remove, and modify the land surface are as follows:

Water in the form of moisture in the atmosphere, rains, springs, streams, waves and glaciers.

Atmospheric agencies by means of winds, changes of temperature and frost.

Any agency that causes rocks to disintegrate or decay, or that removes them, either before or after they decompose, must necessarily influence the form of rock surfaces; but it is also to be noted that an agency may be active at one place and not at another, at one time and not at another, or under some conditions and not under others.

Moisture in the Atmosphere.—This affects the rocks by hastening the chemical decomposition of their constituent minerals.

Rains, Springs and Streams.—The direct mechanical effect of rain falling upon rock is of comparatively little importance; its chief work is done, not in falling, but as it flows away. A part of this water flows away over the surface, and a part sinks into the earth, passes through the soil and rocks, and, sooner or later, emerges as springs.

PLATE XXV.
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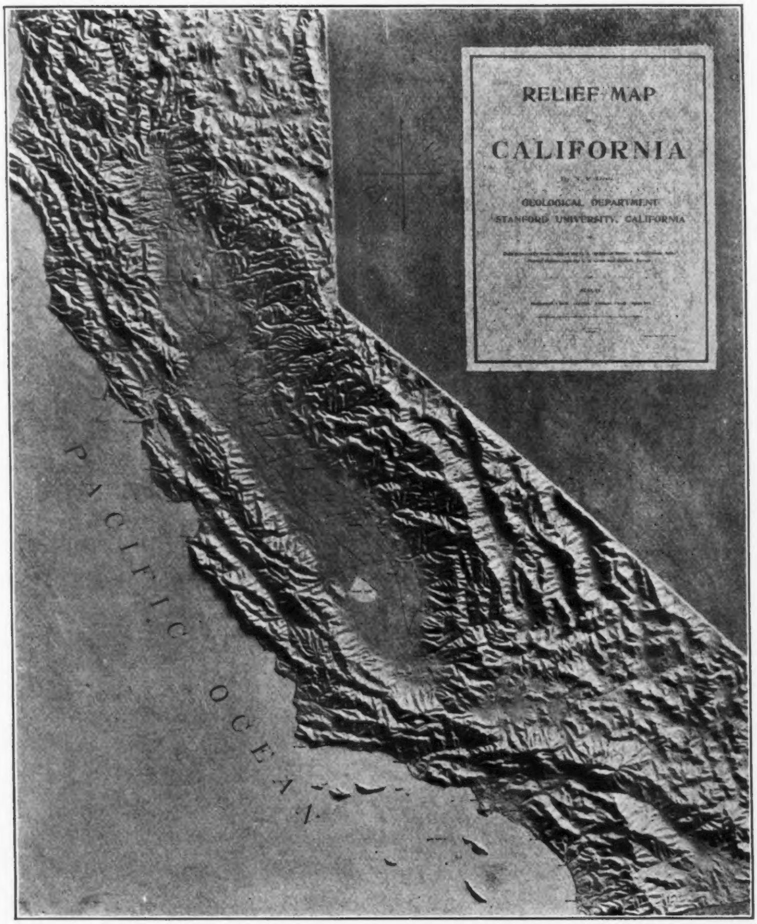
OCTOBER, 1897.
BRANNER ON GEOLOGY AND TOPOGRAPHY.



Before it enters the ground it usually absorbs more or less organic acid of one kind or another, and this acid greatly facilitates its chemical activity. In its passage through the rocks it dissolves more or less mineral matter out of them, and when it emerges as spring water it carries in solution considerable quantities of the mineral constituents of the rocks. No water has ever been found issuing from the earth that did not have more or less mineral matter in solution, while in some of these waters the quantity is enormous. In order to appreciate the amount of rock borne away from the land to the sea in this manner one need only determine the amount removed by a single spring or by a single stream.

In 1887–88 the author carried on a series of observations on the water of the Arkansas River, at Little Rock, where it was found that the dissolved mineral matter in one U. S. gallon of the water varied from 11 to 70 grains. The total quantity of mineral matter removed in solution in one year was 6 828 350 tons.

The materials carried down in solution in this stream are necessarily removed by water from the rocks over the hydrographic basin drained. Similar work is done by all streams, whether large or small, though the amount of material in solution in the water depends more or less upon the character of the rocks of the hydrographic basin. This is only the chemical work of water; its mechanical work will now be considered.

The simple fact that water flows off the land along the depressions is sometimes cited as evidence that these depressions have been made by the water. It is well said by those who object to this explanation of valleys that the water could not possibly flow elsewhere. This fact alone cannot, therefore, be regarded as evidence that valleys are made by streams.

The process of channel cutting will be better understood if a perfectly flat surface is assumed as exposed for the first time to subaerial conditions: rain, snow, frost, streams, changes of temperature, etc. If this flat surface has a gentle slope, the water falling thereon will flow down that slope, and the streams will unite and become larger as they approach its base. In time the running waters will wash out channels for themselves, and still later these channels will be worn deeper and wider. In such a case the channels are evidently cut by the streams.

If, instead of a flat surface, there is, to begin with, an irregular one having the same general slope, the water will seek the depressions from the outset, and the deepening of channels will proceed from these predetermined drainage lines. In both cases the details of the final relief of the region will be the result of the wearing and carrying action of the water. Velocity is what enables water to carry materials heavier than itself. It follows therefore that any increase in the slope of a region must increase the velocity of its streams, while the velocity of the streams increases their carrying power. This relation of force to velocity is expressed by the formula: $F \propto V^2$, in which F is the force of the current and V is its velocity; but the power of the water to move stones varies as the sixth power of its velocity ($F \propto V^6$); that is, by doubling the velocity of a stream, its power to carry is increased sixty-four times.* Hence, any increase of the current of a stream enormously increases its power to sweep along the materials in its channel. It follows that the amount of materials carried along by a stream must vary greatly if the stream itself is subject to fluctuations of volume.

Some streams are always muddy, others only occasionally; but all muddy streams are so because they carry large quantities of mechanically suspended matter. The amount of material carried by such a stream as the Mississippi or the Amazon is almost beyond belief. The observations made by the author upon the Arkansas River, at Little Rock, show that that stream carries, in addition to the dissolved matter already mentioned, an enormous amount of fine sand and clay At times this amounted to more than 700 grains to the gallon. The total amount of mechanically transported sediment carried past Little Rock in the year was 21 471 578 tons. The total amount carried down both in solution and in suspension, in the year was 28 299 929 tons, or equivalent to a cube 749.2 ft. on each side.

Similar determinations of the silts of the Mississippi River show that it carries out of its hydrographic basin every year a mass of mineral matter equal to a cube 1 954 + ft. on a side, without including the dissolved matter. This material can only come from the basins of the streams, and these determinations afford the means of ascertaining the rate at which the land surface is being removed.

* A Treatise on Hydraulics. By F. Merriman, New York, 1891, pp. 251-252. The Suspension of Solids in Flowing Water. By E. H. Hooker, Trans. Am. Soc. C. E., 1896, Vol. XXXVI., pp. 239-340.

Over the entire Mississippi basin erosion goes on at the rate of a foot in 5 000 years; over the Arkansas basin at the rate of a foot in about 9 000 years; over the basin of the Danube at the rate of a foot in 6 846 years; over the basin of the Rhône at the rate of a foot in 1 528 years; over the basin of the Po at the rate of a foot in 729 years, and over the Ganges basin it is at the rate of a foot in 823 years. The importance and bearing of this matter upon topographic relief will be seen presently.

Waves.—Waves do their chief work on the larger bodies of water—oceans, seas and large lakes. Although they are confined in their operations to narrow vertical limits, yet their force is irresistible, their work sharp and well defined, and the length of the lines along which they operate is coextensive with the shores of every ocean, sea and lake on the globe. Their work consists in undercutting the shores, rolling the talus back and forth, and thus grinding up the coarser materials. These materials are either thrown on shore as shingle and sand or are swept out into deeper water by the undertow.

The effect of waves is important only on or near the beach, for they do but little work 20 ft. below low tide or 50 ft. above high tide, except by undermining. When it is recalled that almost every part of the earth's surface has several times passed through a beach condition, the important part the waves have played in the earth's history may be realized.

Glaciers.—In those parts of the earth in which precipitation takes place in the form of snow, the drainage is in the form of ice streams or glaciers. These glaciers carry down upon their surfaces, or within the ice, whatever rock fragments or soils may fall upon them, or that the ice can scrape from its rocky bed; and when the slowly moving ice reaches the point where it melts, this load of débris is dropped, or is swept along by the stream that flows from the melting glacier. The accumulations at the ends of glaciers are known as moraines. If, in time, the glaciers become much shorter, these moraines are left strewn over the ground formerly covered by the ice.

Atmospheric Agencies.

Winds.—In their direct action winds modify the earth's surface by moving sand dunes, by carrying dust in arid regions, and the ashes of volcanoes, and by forming natural sand blasts that cut and polish the rocks.

By their indirect action they are of even more importance, for they effect vegetation on the land, distribute moisture over the earth, help determine the force and direction of ocean currents, and, by raising waves upon water surfaces, enable the waters to undercut their banks and encroach upon the land in some places and to fill up and build beaches, spits, and bars in others.

Changes of Temperature.—These tend to break up rocks by causing them to expand and contract alternately. The minerals of which the the rocks are made do not all expand and contract alike in these changes of temperature, and this tends to pull the rock to pieces and allow acidulated waters to penetrate the crevices and finish the work of destruction.

Frost.—The expansion of water freezing in crevices of the rock hastens its disintegration. By the alternate freezing and thawing the rocks are rapidly broken to pieces and exposed to other decomposing agencies.

The Forms Produced by Destructive Agencies.

Most gorges, cañons, narrow valleys and stream channels are cut in the rocks by streams and other disintegrating and eroding agencies, while topographic prominences are simply the parts left behind in relief. Hills and ridges are therefore high, not because they have been thrust upward, but because the country around them has been worn down more rapidly than they, and it is fair to assume that hills and valleys started very nearly at the same elevation. Although topography is thus chiefly the resultant of rock resistance and rock removal, the resisting powers of rocks vary so much, and the removing agencies work so differently under different conditions, that the problem, in its details, is a complex one.

Other things being equal, topography is dependent upon:

The character and alternation of the rocks.

The geologic structure, or the position of the beds.

The slope of the surface.

The climatic conditions.

Accidents during development.

The initial, primitive conditions or starting point of the drainage.

The length of time the region is exposed to eroding agencies.

The nature and working methods of the eroding agency.

There may be any combination of these influences shaping the topography. However complex the combinations may be, these agencies, when acting alone, produce comparatively simple results.

The Character and Alternation of the Rocks.—It has been stated that erosion goes on over the hydrographic basin of the Mississippi River at the rate of a foot in 5 000 years. It is hardly necessary to say that this erosion is not even, that this foot is not removed over the whole basin alike, but that it is simply an average for the entire area. At some points erosion is almost nil, while at others it is more than 1 ft. in that length of time. If in starting there were a perfectly flat, smooth surface having a gentle slope, the first rains might flow off as if from a sheet of glass; but this water would soon begin to wear here and there, and this wearing would always be more marked in the regions of soft rocks, and in a short time there would be developed, over this once smooth surface, a system of drainage that would come more and more under the influence of the rocks; that is, the channels would be cut deeper and deeper in the soft beds, while the harder ones would be left as prominences. This is clearly shown in Figs. 6 and 7, which are sections across alternate upright beds of hard and soft rocks.

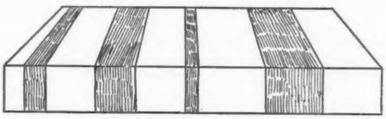


FIG. 6.

Under such circumstances in topographic development the alternation of hard and soft beds must determine the location of valleys and ridges, and any rearrangement of these beds would produce a corresponding rearrangement of the valleys and ridges. In the case of igneous rocks, often the molten material issues through crevices in the older crust, and, as these crevices vary greatly in form, the dikes that fill them vary as much. These dike rocks may be either softer or harder than the beds they penetrate. When they decompose more rapidly than the surrounding rocks, they form depressions; when they are more resisting, they stand out as ridges or walls upon the surface.

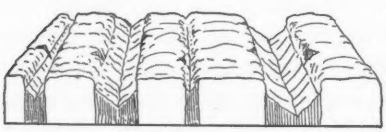


FIG. 7.

When they are of equal resisting power with the adjacent rocks, both wear away together without differentiating the topography; but

whether these dikes make depressions or ridges, no definite law can be laid down for their direction. They sometimes follow parallel lines; sometimes they radiate from centers, and sometimes they seem to bear no apparent fixed relations to each other.

When the rocks are massive and homogeneous throughout, as in the case of granites and some gneisses, there are no marked lines of weakness to encourage selective action of erosion. These rocks, whether in large or small masses, frequently exfoliate or peel off, like the coats of an onion, and produce rounded or ball-like boulders of decomposition, or, on a large scale, they form dome-like hills and mountains.

These forms are characteristic of massive rocks only. They are well illustrated by Stone Mountain, in Georgia,* and by the exfoliated boulders and peaks of Brazil.†

The destructive work done by water in dissolving the mineral constituents of rocks has been spoken of. It follows that the more soluble rocks are affected by chemical activity more rapidly than those less soluble. Limestone is one of the most soluble rocks, and for this reason it is everywhere attacked by water and removed in solution. Water does not confine its action to surface exposures, but penetrates the crevices in the rocks and attacks them often far beneath the surface. The removal of large quantities of rock from deep down below the surface gives rise to caves, sometimes of vast extent. Often the caves are not far below the surface, their roofs give way, the soil slides down and, concealing the old cavities, form what are known as sink-holes. These sink-holes are filled with water, and ponds mark their positions. Caves and sink-holes are confined for the most part to the regions of limestone rocks, and the drainage of such a region is frequently almost all underground.

The Geologic Structure, or the Position of the Beds.—Rocks do not always stand on end, as in the case supposed above, but lie in every conceivable position, from horizontal to vertical, or are even overthrown. They are bent into broad, gentle folds, or squeezed into close wrinkles, or are broken by faults and tipped about in all kinds of positions. It is not necessary to consider what caused these folds; it is

* A Treatise on Rocks, Rock-Weathering and Soils. By Geo. P. Merrill, N. Y., 1897. Frontispiece. North Carolina and its Resources, p. 115.

† Decomposition of Rocks in Braz Bul. Geol. Soc. Am., VIII, pp. 272-277.

enough to know that they exist, and that the axes of the folds are not necessarily parallel.

As a rule, streams and eroding agencies avoid hard rocks and seek out the soft ones. It follows, therefore, that this selective power of water in attacking the rocks must produce different topographic effects according to the positions in which the rocks stand. Indeed, erosion is entirely guided by the rocks in many cases, while in all cases they direct it to a greater or less extent.

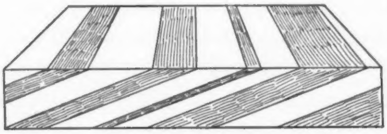


Fig. 8.

Beginning with the flat, smooth surface shown in Fig. 8, as in the previous instance, beds of the same kinds and in the same relations to each other will yield a topography suggested by Fig. 9, the streams following the soft (shaded) beds down the dip. Fig. 10 represents alternate hard and soft (shaded) beds dipping in various directions.

In a region of gently dipping rocks, the streams, following the strike of the beds, move down the slopes at right angles to their courses. Folded beds yield a great variety of forms according to the character of the rocks, the nature of the folds and the age of the topography But they all follow the same general law; erosion removes the soft beds, the harder ones are undermined in some cases, in others they stand out as rock walls.

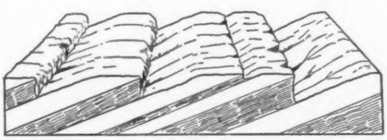


Fig. 9.

The accompanying sketch map (Fig. 11) of the country near Conway, Ark., illustrates well the influence of hard and soft beds in a region of folded rocks. Here the almost unbroken ridges of sandstone can be traced for many miles, swinging around the anticlinal noses and back again around the synclinal spoons like the hard and soft grain of a pine board. Round Mountain in this area is made up of such layers worn away till their remnant looks like a nest of gigantic dishes.

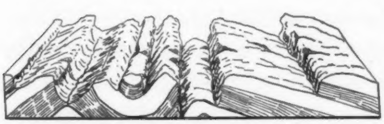


Fig. 10.

When the alternate hard and soft beds are horizontal, as in Fig. 12, the topography is different from any of these forms. In this case the

soft layers may be removed by the action of frost, or weathering in various ways, or by water flowing down the face of the bluff. In either case the removal of the soft layers undermines the hard beds and these eventually break down in blocks. As this process goes on, the profile of the hill does not necessarily change much beyond a certain point until late in the life of the hill, when the hard layers will be removed one by one. Where the beds are thus horizontal they tend to make a terrace or step-like topography. If, in a region of horizontal rocks, the valleys are short and narrow, the slopes will be more or less even, but where the streams, either through the age of the drainage or the width of the valleys, have meandering courses, there

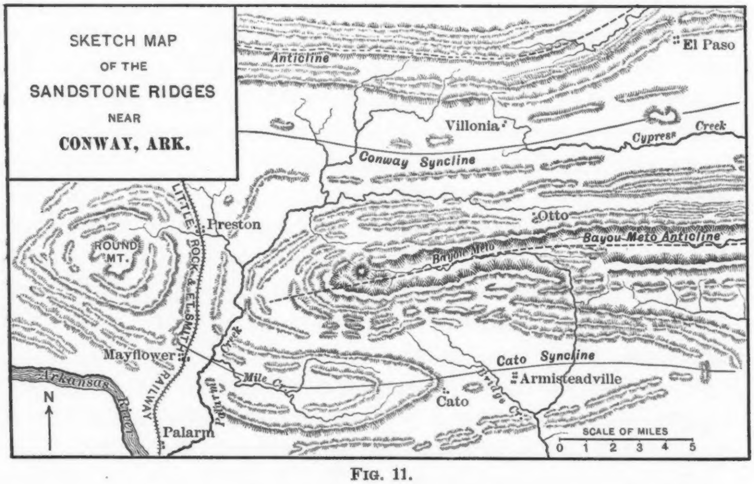


FIG. 11.

will be a marked variation in the slopes of the opposite sides of the streams. Such topography is represented in Fig. 13, which is that of a meandering stream, and is common in certain portions of the Ozark mountains of Arkansas and Missouri.

If, instead of alternating hard and soft beds, we have horizontal rocks nearly uniform in character, they frequently form tall, slender columns; "pulpit rocks," or "chimney rocks," as they are often called. The flatness of a plain is sometimes due to the exposure over its floor of a resisting horizontal bed.

The foregoing discussion of the development of topography in regions of sedimentary rocks has proceeded on the theory that the beds

are uniform in thickness and constant in character. As a matter of fact, there is no such uniformity in the rocks in Nature, and the reason is apparent when the conditions under which the beds have been formed are considered. This variation in thickness and character, this changing of a sandstone into a shale a mile away, and to a limestone further on, yields a corresponding difference in the topography developed from these rocks. Ridges prominent at one place die down and are replaced by valleys and are overlapped by others which here are insignificant and further on are bold and mountainous.

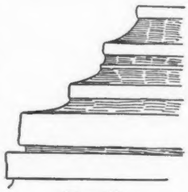


FIG. 12.

It should be noted in regard to the structural forms spoken of here or elsewhere in this paper, that they are not always, or even commonly, seen exposed in Nature. They are, for the most part, concealed by soils, undergrowth or forests, and these structural features can only be made out by the study of wide areas.

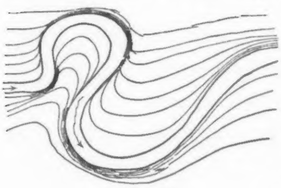


FIG. 13.

Owing to the peculiar method of attack on sea shores—along a horizontal line—structural features yield characteristic forms where cut by waves. Where hard and soft rocks stand on end and their strike is at right angles to the general coast line, the details of the shore will be very irregular owing to the yielding of the soft beds and the resistance of the hard ones, as represented in Fig. 14.

If the beds are tipped up and dip toward the water, the sloping beds will act as an effective breakwater, against which the waves can have but little power. If the beds are horizontal or dip away from the water, the waves will undermine them by attacking the soft beds at their lower exposures.

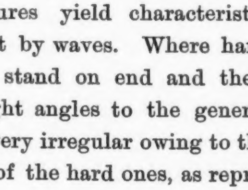


FIG. 14.

Under other heads are discussed various influences that affect the details of topographic relief. Each of these influences is important in its own place, but there is no one of them that so uniformly and so persistently moulds topographic details as does geologic structure. For this reason especial attention should be given to the structure

when it becomes necessary to understand or represent the topography.

The author has been asked to explain the rules for topography suggested by M. L. Lynch, M. Am. Soc. C. E.* The first rule is: that with "a stream flowing east or west * * * the south slope of the valley is generally steeper."

This rule holds good in a region in which the rocks have a gentle south dip, but not elsewhere. If the rocks dip north at the same angle, the steep slope will be on the north sides of the streams.

The other rule is that "in a stream flowing north and south, the east slope of the valley is invariably steeper." * * *

This rule holds in a region where the rocks have a gentle east dip, and not elsewhere. If the rocks dip west and the streams flow north or south, the steep slopes will be on the west sides of the streams; in other words, both rules would be reversed if the dip of the rocks were reversed.

Such rules may be most useful in the regions in which they originate, but they are of no value, and may, indeed, be very misleading in a region of different geologic structure.

The Slope of the Surface.—From what has been said of the transporting power of running water (p. 486), it follows that streams with steep gradients carry away whatever materials lie in or fall into their channels much more rapidly than those with lower gradients, in accordance with the formula $F \propto V^6$. Besides carrying away sand, gravels and boulders, such streams corrade, or, by means of the impact of the moving materials, wear and cut their beds; and as increase of velocity is a factor of so much importance in this connection, it follows that the slope which produces the velocity is the prime factor.

If a slope were perfectly even, if the rocks were of the same character from top to bottom, and if the stream were of the same size throughout, the cutting along its channel would be uniform from one end to the other. But the gradient of every stream varies more or less from one part to another. The rocks also vary, and there is, therefore, a tendency for it to have alternate cataracts and slack currents. The long slopes of mountain chains are frequently not eroded most rapidly at their steepest parts, but this is due to the fact that these steep grades are near the crest where the streams are small. In

* *Trans.* Am. Soc. Civ. Engrs., 1894, xxxi, p. 82.

Fig. 15, if the full line represents the slope of an original surface, the amount of erosion down the slope would be indicated by the distance between the full and dotted lines.

Whatever deviations are found in this rule are due to other conditions, such as variation in the rocks, structure, changes or time. In general the elevation of a country by increasing the slope, affects the topography by allowing the formation of deep valleys and gorges.

Climatic Conditions.—Inasmuch as topographic features are carved chiefly by running water, it follows that there is but little carving done in regions without water. Perfectly arid countries therefore are subject to but little change from this cause.

The wind-blown sands, and the breaking up of surface rocks by changes of temperature, are the most potent agents of change in such regions. In cases, however, in which streams flow through these regions, they produce very marked topographic effects, owing to the fact that they erode their beds and clear their channels, while the walls forming their banks are but little affected by the climate.

FIG. 15.

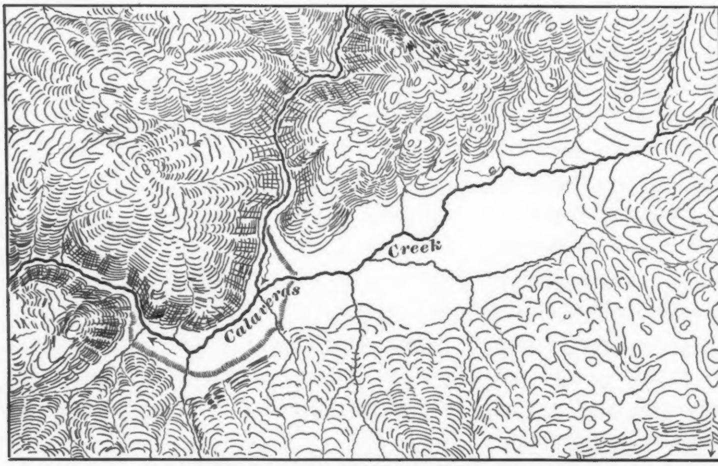
There is no more remarkable illustration of this peculiarity of the work of streams in an arid region than that of the Grand Cañon of the Colorado, where the Colorado River, rising in a region of heavy precipitation, in the Rocky Mountains and Wahsatch Mountains, flows southwestward across the arid regions of Southern Utah, Northern Arizona and Southern California.

Accidents During Development.—The crust of the earth is nowhere perfectly stationary, but is constantly, though for the most part imperceptibly, rising or sinking. Now, if elevation takes place across the channel of a stream, the stream will cut through the obstruction if it does not rise too rapidly. In most cases such changes during the life history of a stream, do not involve great elevations, but in some instances there is the spectacle of a river cutting a deep gorge through a mountain.

If an elevation across a valley takes place more rapidly than the stream can cut, a lake will be formed. Such instances are known, but they are not common. In a mountainous region the streams are rapid; therefore they cut faster than they otherwise could, and obstructions, in order to make lakes, must rise too quickly to be cut down at an

equal rate. A lake made in this way is soon filled up with silt. Immediately thereafter the outlet cuts the dam down slowly, and the stream sinks through the silts of the former lake, leaving terraces on the sides of the valley.

Calaveras Valley in Santa Clara County, California, was formed in the manner here indicated. The accompanying sketch map, Fig. 16, shows the flat floor of this valley with steep mountains on all sides. The obstruction was at the lower or northern end of the valley, and is now being removed by the stream. In such instances the downthrow must always be on the up-stream side of the fault.



SKETCH MAP OF CALAVERAS VALLEY, CALIF.

ONE MILE

FIG. 16.

The Initial, Primitive Conditions or Starting Point of the Drainage.—It often happens that folded and faulted rocks of various characters have been sheared or smoothed off by erosion, and that the area has then been submerged, and sedimentary beds have been laid down unconformably on the older rocks; or lava sheets have been spread over these eroded beds without their being submerged. Whatever the drainage and topography may have been before the lava was spread over the area, or before the superposition of the new sediments, the new drainage will be more or less different from the old on account of the form of the new surface. The streams, starting under the guidance

of the new topography, begin to cut their channels through the new rock, and sooner or later reach the old buried rocks. By the time the buried topography is reached, the stream is so closely confined to its channel that it is obliged to cut through the underlying rocks and to cling to its new channel regardless of the old topography. Such a system of streams is called a superimposed draining, on account of its being let down from overlying beds regardless of the rocks in which it now runs. It should be noted, however, that when a buried topography is uncovered in this way, although the older rocks are unable to bring the drainage under immediate control, there is a constant tendency in that direction. Streams can in this way cut hills and ridges in two, but the rocks that form such ridges are simply notched like a board; lateral streams soon bring them into relief again, and the continuity of the beds can be traced across the principal streams. Erosion seeks out the soft beds again and avoids the hard ones—it goes in the direction of least resistance. The result is that the smaller streams are soon brought again under the control of the structure. Aside from the principal drainage lines, the chief topographic features, even in the case of a superimposed drainage, are controlled by the geologic structure.

The Length of Time the Region is Exposed to Eroding Agencies.—It has already been shown that when destructive agencies get access to a piece of the earth's land surface they begin immediately to attack it, to cut it down and wash it into the ocean. The general tendency of this operation is gradually to reduce the land surface to a low level. Before this level is reached, however, the topography passes through a series of changes, and these changes vary according to the characters of the rocks, geologic structure, climatic conditions, accidents during the period, slope of the country, etc.; or, to put it differently, starting with a given piece of structure, the topography will not always remain the same, even in form, but will vary more or less with its age or with the length of time it is exposed to eroding influences. It is generally agreed that sharp rugged outlines, high and steep relief, waterfalls and rapid streams are characteristic of new topography, and that low relief, rounded outlines, and sluggish streams indicate an old topography. Within certain limits these are characteristic features of old and new topography, but there are many important exceptions.

The Nature and Working Methods of the Eroding Agency.—With important exceptions erosion is done only by water and by ice in motion. The cutting of gullies, cañons and valleys, by streams, has already been explained. The removal of the walls above the stream-bed is greatly hastened by the changes of temperature and especially by the action of frost which loosens and disintegrates the rocks and causes them to slide down the slopes. When precipitation is only in the form of snow, the drainage of the region is effected by glaciers. These streams of ice follow the low ground like streams of water, and carry upon their surfaces, or within their bodies, or push over their rock floors, the soil and rock fragments that come within their reach. The stones, held fast by and pushed along in the ice, grind and wear away the hard rocks in place, rounding off the projections on the up-stream side. In cases of continental glaciers, such as those which now cover the antarctic regions and most of Greenland, it is reasonable to suppose that the up-stream sides of the hills that lie buried beneath these ice sheets are worn more than the down-stream sides. Geologists have found that a large part of the North American continent, nearly all the islands of Great Britain, all of Scandinavia, and large portions of Northern Europe, were once buried beneath a similar sheet of ice. This ice moved, not from the north toward the south as was formerly supposed, but from certain centers outward. It everywhere affected the topography, in many cases leaving the hills more or less rounded on the uphill side, and everywhere strewing the débris over the country, and frequently piling it up in heaps and lines or moraines. The topography produced by ice is characteristic, and there is usually a strong contrast between glaciated and non-glaciated areas, even when the rocks in each are the same.

After this brief statement of the processes by which topographic forms originate and change, it is hoped that the original proposition may be accepted, at least to this extent: that there is not, and cannot be, a fixed rule for all topographic forms, and that in order to understand topography one must understand geology.

"That none but a geologist can make a map is evidently true from the fact that we only see what we look for, and the geologist alone looks for surface indications of internal structure; he knows, therefore, the importance and significance of what to any other man is nothing, or at best a curiosity." *

* Manual of Coal and its Topography. By J. P. Lesley. Philadelphia, 1856, p. 192.

1897. OCTOBER. No. 8.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS.

THEORY OF THE IDEAL COLUMN.

By WM. CAIN, M. Am. Soc. C. E.

TO BE PRESENTED DECEMBER 1ST, 1897.

The usual derivation of Euler's formula for long columns does not show that it gives the load at which bending just begins. The following analysis brings out this important fact. It further gives an expression for the maximum deflection for a load very slightly exceeding that given by Euler's formula, and confirms that formula as a practical one within the usual limits.

The following theory, as to method, is a closer approximation to the truth than the usual analysis, as the original (straight) and final (curved) axes of the column are nowhere confounded as in the common theory, where an approximation to the radius of curvature is assumed at the start. Here, the correct expression for the radius of curvature $\rho = \frac{d\,s}{d\,\theta}$ is used, and the analysis, as a whole, seems as accurate as the subject admits. This closer approximation is not an aim in itself, but only a necessary means to bring out and properly interpret well-known results.

The columns to be examined will be regarded as "ideal" or as prismatic homogeneous columns, having the force P applied at one

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

end, in the direction of the axis or line through the centers of gravity of the cross-sections.

In Fig. 1, $A\ C\ B$ represents the original straight axis of the column, and the force P is supposed applied at A in the direction $A\ C\ B$. It is to be understood throughout that the force P is never to be so large as to cause the stress in any fiber to exceed the limit of elasticity.

First, let the column be supposed pivoted at the ends at A and B. As the column is straight and homogeneous, the force P will compress it, so that its primitive length, $A\ C\ B = a$ ins., is changed to $A'\ C\ B = a_1$ ins.; but the column will remain straight, as the stress is uniform on each cross-section. The weight of the column is neglected in this investigation. Calling $A =$ the area of cross-section in square inches, and $E =$ the modulus of elasticity in pounds per square inch, $A'\ C\ B = a_1 = a\left(1 - \frac{P}{E\,A}\right)$.

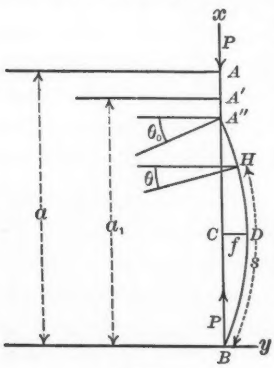


FIG. 1.

Now, suppose a lateral force to bend the column; if P is large enough, it remains bent after the lateral force is removed, and the axis takes the position $A''\ H\ D\ B$ under the force P alone.

As the length of the axis is not altered by flexure, the length of the curved axis $A''\ H\ D\ B = a_1 = a\left(1 - \frac{P}{E\,A}\right)$.

In Fig. 1 call:

$I =$ moment of inertia of cross-section at H about an axis projected in H,

$\theta =$ angle (in circular measure) the section at H makes with its original horizontal direction,

$\theta_0 =$ value of θ at top of bent column A'',

$s =$ length of arc $B\ D\ H$,

$\rho =$ radius of curvature at $H = \frac{d\,s}{d\,\theta}$,

$f =$ maximum deflection $= C\ D$.

The origin of co-ordinates will be taken at B; x vertical (along primitive axis) and y horizontal.

If the primitive straight axis $A\ C\ B$ is divided into N equal parts, each equal to $\frac{a}{N}$, after compression of the axis from the length $A\ C\ B = a$ to the length $A'\ C\ B = a_1$, each of these parts will now have the length $\frac{a_1}{N}$, and the same is true for each of the N equal parts into which the bent axis $A''\ H\ D\ B$ is divided, since arc $A''\ H\ D\ B = A'\ C\ B = a_1$.

In Fig. 2 is shown a portion of the bent column. The original length $H\ J = \frac{a}{N}$ of axis has been changed to length of arc $H\ H' = \frac{a_1}{N}$. On drawing a section $F\ F'$ through H' parallel to that at H, making $F\ H' = G\ H' = V =$ distance from axis to most compressed fiber, then on bending (after the uniform compression has been exerted that changes length $\frac{a}{N}$ of axis to $\frac{a_1}{N}$), the section $F\ F'$ at H', originally parallel to that at H, rotates, relatively to it, to position $G\ H'\ G'$, the points F and F' describing, relatively to G and G', circular arcs $F\ G$ and $F'\ G'$. Call length of arc $F\ G = K$.

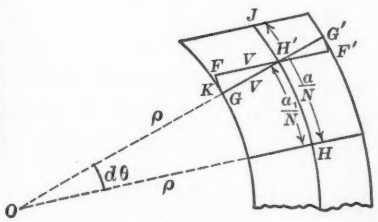


FIG. 2.

For a small deflection f (Fig. 1), the component of P parallel to the section at H is very small and may be neglected, so that the sections at H and H' (Fig. 2), originally normal to the axis, remain so after flexure. The angle $d\,\theta$ between the final sections at H and $H' =$ angle $F\ H'\ G$. If the arc $H\ H'$ is regarded as a circular arc, described with radius ρ from center O, which is admissible, as N will be supposed to increase indefinitely in going to the limit, it is seen that the circular sectors $O\ H\ H'$ and $F\ H'\ G$ are similar, having the same central angle; hence,

$$\rho : \frac{a_1}{N} :: V : K \therefore \rho = \frac{a_1\ V}{N\ K}.$$

It is seen from the figure that the bending alone does not change the length of any portion of the axis as $H\ H'$ (Fig. 2), as was assumed above.

If S designates the stress in the fiber at G of cross-section unity, due to bending alone, then $S = M\frac{V}{I}$ by a well-known formula, where

M = bending moment = $P\,y$, and y (Fig. 1) is the ordinate to the axis at the section considered.

By another standard formula,

K = change of length in fiber at G (Fig. 2).

$= S \times$ old length of fiber $H\,J \div E$.

$$= \frac{S\,\frac{a}{N}}{E} = M\,\frac{V}{I}\,\frac{a}{N\,E}$$

$$\therefore\ \rho = \frac{a_1}{a}\,\frac{E\,I}{M} = \frac{d\,s}{d\,\theta}$$

The fact that, by the usual hypothesis, the change of length K, due to flexure only, varies with the stress and the old length of fiber has been especially emphasized by Henry S. Prichard, M. Am. Soc. C. E., in his notable contribution to the theory of "The Ideal Column."* The author's indebtedness to Mr. Prichard, in the previous analysis, will be evident on comparison.

In the correct value of $\rho = \frac{d\,s}{d\,\theta}$ given above, it is seen that N has been eliminated, hence the result is true at the limit, as N indefinitely increases and H' approaches H indefinitely.

From the value of ρ above, placing Py for M and putting $m = \left(\frac{a}{a_1}\,\frac{P}{E\,I}\right)$, there results,

$$\frac{1}{\rho} = \frac{d\,\theta}{d\,s} = \left(\frac{a}{a_1}\,\frac{P}{E\,I}\right) y = m\,y. \qquad (1)$$

m is here constant for a constant P. Differentiating (1) as to s,

$$\frac{d^2\,\theta}{d\,s^2} = m\,\frac{d\,y}{d\,s} = -\,m \sin\theta. \qquad (2)$$

Multiplying by $2\,d\,\theta$ and integrating,

$$\left(\frac{d\,\theta}{d\,s}\right)^2 = 2\,m\cos\theta + C.$$

At A'' where $\theta = \theta_o$ and $\frac{d\,\theta}{d\,s} = 0$ from (1) since $y = 0$, $C = -\,2\,m\cos\theta_o$.

$$\therefore \left(\frac{d\,\theta}{d\,s}\right)^2 = 2\,m\,(\cos\theta - \cos\theta_o) \qquad (3)$$

or

$$\frac{d\,\theta}{\sqrt{2\,(\cos\theta - \cos\theta_o)}} = \sqrt{m}\,.\,d\,s \qquad (4)$$

* *Engineering News*, May 6th, 1897. Appendix A (3a).

If θ becomes zero i times between B and A'', the integral of the left member between B and A'' is $i\,\pi\left(1+\frac{\theta_o^2}{16}\right)$ on neglecting the fourth and higher powers of θ_o (see Appendix). The integral of the right member between the same limits is $\sqrt{m}\,.\,a_1$; hence to this approximation,

$$i\,\pi\left(1+\frac{\theta_o^2}{16}\right)=a_1\sqrt{m}\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Equations (1) and (3) applied to points like D, for which $\theta=0$, $y=f$, give $\frac{d\,\theta}{d\,s}=m\,f$; $\left(\frac{d\,\theta}{d\,s}\right)^2=2\,m\,(1-\cos\theta_o)$; or, since in consequence of θ_o being very small, $2\,(1-\cos\theta_o)=2\,(1-1+\frac{1}{2}\,\theta_o^2)=\theta_o^2$, on neglecting as before the fourth and higher powers of θ_o, the two previous equations give,

$$m^2 f^2=m\,\theta_o^2\;.\cdot.\;\theta_o^2=mf^2\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

θ_o can now be eliminated by substituting this value in (5), giving,

$$i\,\pi\left(1+\frac{mf^2}{16}\right)=a_1\sqrt{m}.$$

On substituting the value of $m=\frac{a}{a_1}\,\frac{P}{EI}$,

$$f^2=16\,\frac{a_1}{a}\left[\frac{\sqrt{aa_1}}{i\,\pi}\sqrt{\frac{EI}{P}}-\frac{EI}{P}\right]\ldots\ldots\ldots\ldots\ldots(7)$$

where $a_1=a\left(1-\frac{P}{EA}\right)=A'\,CB=A''\,HDB$ (Fig. 1).

In deriving this formula (7), three approximations have been introduced:

(1) Neglecting the shearing component of P in finding the formula for ρ, (2) and (3) neglecting the fourth and higher powers of θ_o in comparison with θ_o^2 in equations (5) and (6).

As in the practical application of (7) to deriving Euler's formula, f will be supposed very small—as near zero as we please; the errors introduced will not appreciably alter the result.

This formula (7) is given by Bresse* in another form and should be called Bresse's formula. His derivation of (7) offers some objections, which the writer has endeavored to remove in the analysis above. In an article on "Long Columns," in the *Journal* of the Franklin Institute for July, 1887, the author gave Bresse's original analysis, together

* *Mécanique Appliquée*, première partie, p. 372.

with a discussion and the derivation of other formulas from a different standpoint. It is easy to clear away the apparent obscurity in Bresse's analysis, which furnishes the basis of the preceding discussion, but the method adopted above is so simple and clear that it will doubtless prove more satisfactory. Some very important conclusions follow from equation (7).

The least value of P (call it P_1), at which the preceding theory begins to be applicable, corresponds to $f = 0$ and $i = 1$, corresponding to the simple case of curvature given by Fig. 1:

$$\therefore P_1 = \frac{\pi^2 E I}{a\, a_1} \qquad (8)$$

This is exactly the modified Euler's formula found by Mr. Prichard,* as should be the case; for as f approaches zero, the bent axis tends to coincidence with the straight axis, so that the usual approximation $\frac{1}{\rho} = \frac{d^2y}{dx^2}$, which involves this coincidence in part, should lead to the same formula as that derived from (7) for $f = 0$. For i repetitions of the curvature shown by Fig. 1, $P = \frac{i^2 \pi^2 E I}{a\, a_1}$.

As $a_1 = a \left(1 - \frac{P_1}{E\,A}\right)$ is very nearly equal to a; on putting a for a_1 in (8), the usual Euler's formula is found. Formula (7) shows that P_1 is the load at which bending just begins, for $i = 1$, or the case of curvature shown by Fig. 1. This very important fact is not brought out by the usual analysis. The superiority in the Bresse analysis over the common one is thus plain, and this gain in interpretation of results is further shown by aid of (7), in proving that a very small increase in P over that given by (8) will cause a sensible deflection and rupture, so that Euler's formula is thus demonstrated to give a value of the load at which not only bending just begins, but also, if a very small proportionate increase in the load is made, rupture will occur; so that Euler's formula is practically a formula for rupture.

As a numerical example take a column composed of two 5-in. channels. $A = 3.9$, $I = 14.8$, $a = 325$ (the inch being the unit), and $E =$ 29 000 000 lbs. per square inch.

From (8), placing a for a_1, $P_1 = 40\,105$ lbs.

Suppose an increase of load of only 5 lbs. $\therefore P = 40\,110$ lbs. in (7), where again place $a_1 = a$ approximately, and it is found that

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* *Engineering News* for May 6th, 1897, p. 277.

$f = 3.44$ ins. The increase of a few pounds more would lead to rupture, so that (8) gives practically the load corresponding to rupture.

This can be shown more generally in a way suggested, in part, by Mr. Prichard, who kindly gave the author valuable suggestions in criticising his paper before publication.

Call P_2 a value of P slightly greater than P_1, as given by (8), and $a_2 = \text{arc } A'' H D B = A' C B$ (Fig. 1) corresponding to P_2. From (7), replacing a_1 by a_2 and P by P_2 and substituting,

$$a_2 = a_1 - a \frac{P_2 - P_1}{E A} = a_1 \left(1 - \frac{P_2 - P_1}{E A}\right) \text{ very nearly.}$$

$$\therefore a_2 = \frac{\pi^2 E I}{a P_1}\left(1 - \frac{P_2 - P_1}{E A}\right) \text{ by aid of} \ldots\ldots\ldots\ldots (8)$$

$$f^2 = 16 \frac{a_2}{a}\left[\sqrt{1 - \frac{P_2 - P_1}{E A}} \; \frac{E I}{\sqrt{P_1}\sqrt{P_2}} - \frac{E I}{P_2}\right] \ldots\ldots (9)$$

where $\frac{a_2}{a} = 1 - \frac{P_2}{E A} = 1$ nearly.

As an example, using the same cross-section of column as above, $A = 3.9$, $I = 14.8$, $E = 29\,000\,000$, $P_2 = 40\,004$, $P_1 = 40\,000$,* so that $P_2 - P_1 = 4$ lbs. only; from (9),

$$f = 3 \text{ ins. nearly.}$$

By a well-known formula, the total maximum stress on the concave side (at D, Fig 1), due both to the uniform compression and that caused by flexure, is, $\frac{P_2}{A} + \frac{P_2 f V}{I} = 30\,560$ lbs., so that the limit of elasticity has been slightly exceeded.

An increase of load of only 4 lbs. thus causes the maximum stress per square inch to change from $P_1 \div A = 10\,260$ lbs. to $30\,560$ lbs. It is plain that a few pounds more, say about 10 lbs., added to $P_1 = 40\,000$, would cause rupture.

This shows that Euler's formula gives, not only the load at which bending just begins, but practically the load at which rupture occurs.

The increase in f is so rapid for a very small addition to P_1 that rupture may be said to ensue for P_1 as found from (8), or the ordinary Euler's formula where a_1 is replaced by a.

The two conclusions, first, that Euler's formula gives the load at which bending just begins, and, second, that a very small increase to

* a, the corresponding length of column, can be found from (8) if desired. It is not needed in what follows.

this load insures failure of the column, have been often assumed without proof. They are here rigorously proved.

For the case of the column "fixed at both ends," the line $G\ B\ D\ A''\ H$ (Fig. 3), will represent the axis, the part $B\ D\ A''$ corresponding to the similarly marked part in Fig. 1, and the portions $A''\ H$, $G\ B$, with vertical tangents at G and H, being identical with $D\ A''$ or $B\ D$ inverted. Arc $E\ H\ D\ G\ F$ is a portion of the axis for pivoted ends where $i = 3$ in equation (7); hence, in Fig. 3, P acts along the chord $A''\ B$, giving bending moments at H and G sufficient to insure vertical tangents there.

Regarding, as before, $a_1 = B\ D\ A''$ and $a =$ length of same before compression, then for column $G\ D\ H$ "fixed at ends,"

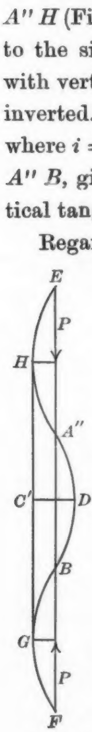

FIG. 3.

$2a =$ length of unstrained column $= l$,
$2a_1 =$ " strained " $= l_1$, and
$f' = C'\ D = 2f$.

In (7) on putting $\frac{1}{2}f'$ for f, $\frac{1}{2}\ l$ for a, and $\frac{1}{2}\ l_1$ for a_1, an expression for f' can be found. The corresponding modified Euler's formula can be found from this directly by making $f' = 0$, or more simply from (8),

$$P_1 = \frac{4\ \pi^2\ E\ I}{2\ a\ .\ 2\ a_1} = \frac{4\ \pi^2\ E\ I}{l\ l_1} \qquad \text{(10)}$$

For the column fixed at one end, pivoted at the other, several cases present themselves. If the upper end is entirely free to move laterally, then $D\ A''$ (Fig. 1) will represent the axis for no repetitions of the simplest case of curvature.

Therefore, from (8),

$$P_1 = \frac{\pi^2\ E\ I}{4\ \frac{a}{2}\ \frac{a_1}{2}} = \frac{\pi^2\ E\ I}{4\ l\ l_1} \qquad \text{(11)}$$

where $l =$ length of unstrained column. If, however, the framing, of which the post constitutes a part, admits little lateral movement at the top of the post, the part of the axis $G\ B\ D\ A''$, Fig. 3 (fixed at G and free at A''), may more closely approximate to the truth. From (8),

$$P_1 = \frac{9}{4}\ \frac{\pi^2\ E\ I}{\frac{3}{2}\ a\ \frac{3}{2}\ a_1} = \frac{9}{4}\ \frac{\pi^2\ E\ I}{l\ l_1} \qquad \text{(12)}$$

where $l =$ unstrained length of axis;
$l_1 =$ strained " " "

In case A'' is compelled to remain in the same vertical line with G, an investigation, not given here, will show that $\frac{9}{4}$ in the last formula will be replaced by 2.05, which differs from it but slightly.

In all of these formulas $l_1 = l\left(1 - \frac{P_1}{E A}\right)$. This value can be substituted and the resulting quadratic solved for P, but there is no practical gain in this more exact method. It is always practically exact, where l_1 is involved simply as a factor, to let $l_1 = l$, in which case the preceding formulas (8), (10), (11) and (12), give the loads at which bending begins and failure speedily follows.

If there happens to be a greater number of repetitions of the simple curvature than that assumed above, then P_1 is greater. Pure theory cannot resolve this question, and experiment has to be appealed to in practice to decide upon the most probable case of curvature for the different end conditions.

If l = length of column, r = radius of gyration of cross-section about an axis projected in H (Fig. 1), and if $l_1 = l$ approximately, the preceding formulas can be expressed by

$$P = n\,\frac{\pi^2 E I}{l^2} = n\,\frac{\pi^2 E A r^2}{l^2} \quad\text{.................(13)}$$

or,

$$\frac{P}{A} = (n\,\pi^2 E) \div \left(\frac{l}{r}\right)^2 \quad\text{...................(14)}$$

where the theoretical values of n generally adopted are, for both ends pivoted, $n = 1$; one end fixed, the other pivoted, $n = \frac{9}{4}$; both ends fixed, $n = 4$, as given above.

Calling S_e the elastic limit of the material, if (14) gives the unit stress on the cross-section $\frac{P}{A} > S_e$, the formula is inapplicable, as it was expressly assumed from the beginning that the limit of elasticity was not to be exceeded.

For a value of $\frac{l}{r}$ in (14) which gives $\frac{P}{A} = S_e$, the column will fail (on a very slight increase of P) by bending, and the same is true for greater values of $\frac{l}{r}$. For less values of $\frac{l}{r}$, $\frac{P}{A} > S_e$.

The limiting value of $\frac{l}{r}$, below which (14) is inapplicable, and

above which it is applicable, is found from (14) by putting $\frac{P}{A} = S_e$,

$$\therefore \text{ limit } \frac{l}{r} = \sqrt{\frac{n \pi^2 E}{S_e}} \qquad (15)$$

At and above this limit, formula (14) gives the average unit stress that practically leads to failure by bending, on supposing a lateral force applied that causes bending and then conceiving the force removed. Of course, in actual columns, the bending results from crookedness, lack of homogeneity or eccentric application of the load, so that no imaginary force has to be temporarily applied to start the bending. Below the limit (15) two cases appear: one, for a single application of a load causing immediate failure, and, two, for millions of applications of a load leading ultimately to failure.

In the first case, for short, ideal columns, of sufficient length to admit the fractured portions sliding freely off, the average unit stress for failure should correspond to the crushing strength of the material.

Plates XLI and XLII in the paper by T. H. Johnson, M. Am. Soc. C. E., on "The Strength of Columns," * illustrate this view in a general way. Here, the average unit stress causing failure for a single application of a load gradually applied, for $\frac{l}{r}$ between 10 and 30 varied for wrought-iron columns with fixed ends from about 34 000 to 55 000 lbs. per square inch, the average being about 45 000.

Mr. Johnson quotes Mr. Christie as giving the modulus of rupture of wrought-iron beams as 44 800. As the law connecting deformation with stress is not known, when the stress exceeds the elastic limit, no formula for failure of ideal columns below the limit (15) for a single application of the load can be given. At the limit, for the columns just mentioned, $\frac{P}{A} = S_e = 29\,000$ and for $\frac{l}{r} = 20$, $\frac{P}{A} = 45\,000$ say, but between these limits no formula for failure can be given with the present knowledge of the subject.

In the second case cited above, for millions of applications of a load, if it is assumed after Wöhler that any load above the elastic limit, repeated millions of times, will lead to failure, then

$$\frac{P}{A} = S_e \qquad (16)$$

* *Transactions* Am. Soc. C. E., Vol. xv, p. 517.

will represent the unit stress leading to failure after millions of repetitions of the load, when $\frac{l}{r}$ is less than the value given by (15).

In this case, if successive values of $\frac{l}{r}$ are laid off as abscissas, and the corresponding values of $\frac{P}{A}$ as ordinates, then the theoretical locus for the failing unit stress for the ideal column will be the straight line (16) for $\frac{l}{r}$ varying from 0 to the value given by (15), after which it coincides with the curve given by Euler's equation.

The fact must not be lost sight of though, that a single application of the critical load given by (14) leads to failure when $\frac{l}{r}$ exceeds the limit (15), while a very great number of applications of the load given by (16) is required for failure for $\frac{l}{r}$ below the limit. The degree of security is thus not the same for the straight and curved portions of the locus. The author is not aware of this distinction having been noted before.

This completes what the author had to say about the ideal column. The actual column is purposely not touched on, as it is first of all necessary to have clear and sound views with reference to the ideal column. This must be the apology for the rather long mathematical discussion which is given. The value of f in (7) is seen to lead to the most important practical conclusions, which may here be recapitulated:

I. Euler's formula is deduced from (7).

II. It follows from (7) that Euler's formula corresponds to incipient bending of the column.

III. By aid of (7) it is shown that a very small increase to the load given by Euler's formula will lead to a considerable bending of the column, and consequent failure from the combined stresses due to the uniform compression and flexure.

IV. Hence, practically, Euler's formula gives the load that causes failure when $\frac{l}{r}$ exceeds a certain limit given by equation (15).

APPENDIX.

From the formula, x being small,

$$\cos x = 1 - \frac{x^2}{2} + \frac{x^4}{2.3.4} - \ldots$$

we have,

$$2\,(\cos\theta - \cos\theta_o) = \theta_o^{\,2} - \theta^2 - \tfrac{1}{12}\,(\theta_o^{\,4} - \theta^4)$$
$$= (\theta_o^{\,2} - \theta^2)\,[1 - \tfrac{1}{12}\,(\theta_o^{\,2} + \theta^2)]$$

on neglecting powers of θ higher than the fourth.

Whence,

$$2\,i\int_0^{\theta_o} \frac{d\,\theta}{\sqrt{2\cos\theta - \cos\theta_o}}$$
$$= 2\,i\int_0^{\theta_o}\Big[1 - \tfrac{1}{12}\,(\theta_o^{\,2} + \theta^2)\Big]^{-\frac{1}{2}} \frac{d\,\theta}{\sqrt{\theta_o^{\,2} - \theta^2}}$$
$$= 2\,i\int_0^{\theta_o} (1 + \tfrac{1}{24}\,\theta_0^{\,2} + \tfrac{1}{24}\,\theta^2)\ \frac{d\,\theta}{\sqrt{\theta_o^{\,2} - \theta^2}}$$
$$= i\,\pi\left(1 + \frac{\theta_0^{\,2}}{16}\right)$$

as given in equation (5).

Vol. XXIII. NOVEMBER, 1897. No. 9.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

SOCIETY AFFAIRS.

PAPER.

The prices of publications are as follows: Proceedings, $6 per annum; Transactions, $10 per annum. Postage will be added when they are sent to foreign countries.

American Society of Civil Engineers.

OFFICERS FOR 1897.

President, BENJAMIN MORGAN HARROD.

Vice-Presidents.

Term expires January, 1898:
WILLIAM R. HUTTON,
P. ALEXANDER PETERSON.

Term expires January, 1899:
GEORGE H. MENDELL,
JOHN F. WALLACE.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOHN THOMSON.

Directors.

Term expires January, 1898:
AUGUSTUS MORDECAI,
CHARLES SOOYSMITH,
GEORGE H. BENZENBERG,
GEORGE H. BROWNE,
ROBERT CARTWRIGHT,
FAYETTE S. CURTIS.

Term expires January, 1899:
GEORGE A. JUST,
WM. BARCLAY PARSONS,
HORACE SEE,
JOHN R. FREEMAN,
DANIEL BONTECOU,
THOMAS W. SYMONS.

Term expires January, 1900:
JAMES OWEN,
RUDOLPH HERING,
HENRY G. MORSE,
BENJAMIN L. CROSBY,
HENRY S. HAINES,
LORENZO M. JOHNSON.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

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HORACE SEE,
WM. BARCLAY PARSONS,
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JOHN R. FREEMAN,
JAMES OWEN.

On Publications:
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JOHN F. WALLACE,
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On Library:
AUGUSTUS MORDECAI,
DANIEL BONTECOU,
CHARLES WARREN HUNT
WM. BARCLAY PARSONS,
HENRY G. MORSE.

Special Committees.

ON UNIFORM STANDARD TIME:—Sandford Fleming, Charles Paine, Theodore N. Ely, J. M. Toucey, T. Egleston.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf, Thomas Rodd, A. E. Hunt.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

The rooms of the Society are open from 9 to 17 o'clock each business day, except Saturday (when they are closed at 15 o'clock), Wednesday evenings, and at other times on application to the Janitor.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

Vol. XXIII. NOVEMBER, 1897. No. 9.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

November 3d, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 70 members and 11 visitors.

The minutes of the meetings of October 6th and 20th, 1897, were approved as printed in *Proceedings* for October, 1897.

A paper by Corydon T. Purdy, M. Am. Soc. C. E.. entitled "Can Buildings Be Made Fire Proof?" was presented by the author. The Secretary read correspondence on the subject from Messrs. Gustave Kaufman and Emil Swensson (jointly). The paper was discussed orally by Messrs. Howard Constable, John R. Freeman, Henry C. Meyer, L. L. Buck, Henry S. Pritchard, and the author. Mr. Constable exhibited several drawings, and a number of specimens of terracotta and other fire-proof material, etc.

Ballots were canvassed and the following candidates declared elected:

As Members.

Clarence Coleman, Marquette, Mich.
Amory Prescott Folwell, Glens Falls, N. Y.
Samuel Hill Lea, Delaware City, Del.
John Mitchell Moncrieff, Newcastle-upon-Tyne, England.
Theodore Smidt Oxholm, West New Brighton, Richmond Co., N. Y.
Fred Stark Pearson, New York, N. Y.
Joseph Leslie Phillips, San José de Gracia, Sinaloa, Mex.
Hiram Phillips, St. Louis, Mo.
William Van Slooten, New York, N. Y.
Willis Benton Wright, New Orleans, La.

As Associate Members.

Stevenson Archer, Greenville, Miss.
James Edwin Boatrite, New York, N. Y.
Tillman Danis Lynch, Thurlow, Pa.
Charles Hatton Mercer, Chicago, Ill.
Edmund Alyth Rhys-Roberts, Buffalo, N. Y.
Walter Alexander Rogers, Chicago, Ill.

The Secretary announced that the last meeting of the Society in the Old Society House would occur on November 17th, 1897, when a paper by John C. Branner, Ph. D., entitled "Geology In Its Relations to Topography," would be presented for discussion.

Adjourned.

November 17th, 1897.—The meeting was called to order at 20.20 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 122 members and 25 guests.

A paper by John C. Branner, Ph.D., entitled, "Geology In Its Relations to Topography," was presented by the Secretary, who also read correspondence on the subject from Messrs. J. J. Stevenson, Benjamin S. Lyman, Henry S. Williams, W. M. Davis, Edward H. Williams and R. A. F. Penrose, Jr.

The paper was discussed by Messrs. J. F. Kemp and James C. Meem.

The Secretary announced the deaths of General James C. Duane, Hon. M. Am. Soc. C. E., and Thomas Doane, M. Am. Soc. C. E.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

November 2d, 1897.—Eleven members present.

Action was taken in regard to members in arrears for dues.

A Committee was appointed to investigate and report to the Board as to the advisability of action, under the resolution passed at the Convention of 1897, in relation to the Sixth Resolution of the Washington Prime Meridian Congress of 1884.

Applications were considered and other routine business transacted.

Adjourned.

ANNOUNCEMENTS.

FORMAL OPENING OF NEW SOCIETY HOUSE, No. 220 WEST 57th STREET.

The Board of Direction has appointed a Committee, consisting of the President, Secretary, Treasurer and the Chairmen of the Finance and Building Committees, to take charge of all the arrangements for the opening of the **New House** of the Society, and the following programme has been decided upon:

The date fixed for the formal opening is **Wednesday, November 24th, 1897,** and on this day the house will be open for inspection by members and their friends from 9 until 2 o'clock.

In the afternoon, beginning at 3.30, formal exercises will be held in the Auditorium. A programme for this meeting is now being arranged by the Committee.

In the evening at 9 o'clock there will be a House Warming, at which dancing may be expected and supper will be served.

Owing to the exigencies of moving it has been found impracticable to keep the books of the Library in such order as to be readily accessible to members. The labor of arranging the books on the shelves is being pushed forward as rapidly as possible, and in individual cases every effort will be made to facilitate the finding of certain books which may be required for consultation.

It is confidently expected that the Library will be at least in working order by December 1st, 1897.

MEETINGS.

Wednesday, December 1st, 1897, at 20 o'clock, the first regular meeting in the **New House, No. 220 West 57th Street,** will be held, at which a paper by William Cain, M. Am. Soc. C. E., entitled "Theory

of the Ideal Column," will be presented. It was printed in the October number of *Proceedings*.

Wednesday, December 15th, 1897, at 20 o'clock, a regular meeting will be held, at which a paper by Spencer Miller, M. Am. Soc. C. E., entitled, "A Problem in Continuous Rope Driving," will be presented. It is printed in this number of *Proceedings*.

DISCUSSIONS.

Discussion on the paper by O. E. Selby, Jun. Am. Soc. C. E., entitled, "Painting the Louisville and Jeffersonville Bridge," which was presented at the meeting of October 20th, 1897, will be closed December 1st, 1897.

Discussion on the paper by Corydon T. Purdy, M. Am. Soc. C. E., entitled, "Can Buildings Be Made Fire Proof?" which was presented at the meeting of November 3d, 1897, will be closed December 15th, 1897.

Discussion on the paper by John C. Branner, Ph. D., entitled "Geology In Its Relations To Topography," which was presented at the meeting of November 17th, 1897, will be closed January 1st, 1898.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

			Date of Membership.
BELL, GILBERT JAMES	350 LaSalle Ave., Chicago, Ill.	Jun. M.	Sept. 7, 1887 Oct. 6, 1897
DE WITT, PHILLIP HOFFECKER	Chf. Engr. and Vice-Prest. Genesee and Wyoming Valley Ry., Caledonia, N. Y.		May 5, 1897
FOLWELL, AMORY PRESCOTT	Glens Falls, N.Y.	Jun. Assoc. M. M.	Feb. 5, 1890 June 7, 1893 Nov. 3, 1897
LAUB, HERMANN	537 Telephone Bldg., Pittsburg, Pa.		Oct. 1, 1897
LEA, SAMUEL HILL	Delaware City, Del.		Nov. 3, 1897
OXHOLM, THEODOR SMIDT	West New Brighton, N. Y.		Nov. 3, 1897
PHILLIPS, HIRAM	306 Oriel Bldg., St. Louis, Mo.	Assoc. M. M.	Jan. 3, 1894 Nov. 3, 1897
PHILLIPS, JOSEPH LESLIE	306 Oriel Bldg., St. Louis, Mo		Nov. 3, 1897
RAYMOND, THOMAS LAIDLAW	Prin. Asst. Engr. of Drainage Comm. of New Orleans, La., Room 22, City Hall, New Orleans, La.		Oct. 6, 1897
VAN SLOOTEN, WILLIAM	Prest. South American Development Co., 35 Wall St., New York City		Nov. 3, 1897
WRIGHT, WILLIS BENTON	Room 22, City Hall, New Orleans, La.		Nov. 3, 1897

ASSOCIATE MEMBERS.

BARBER, WILLIAM DAVIS	583 Evergreen Ave., Chicago, Ill.		Sept. 1, 1897
DIEBITSCH, EMIL	177 Schermerhorn St., Brooklyn, N.Y.	Jun. Assoc. M.	Feb. 28, 1893 Oct. 6, 1897
EDER, HENRY JAMES	123 West 80th St., New York City	Jun. Assoc. M.	June 5, 1894 Sept. 1, 1897
LOCKE, WILLIAM WILLARD	Sanitary Engr., Health Dept., 177 Columbia Heights, Brooklyn, N. Y.		Oct. 6, 1897
MERCER, CHARLES HATTON	50 Wabansia Ave., Chicago, Ill.		Nov. 3, 1897

RHYS-ROBERTS, EDMUND ALYTH	Engr., Buffalo Structural Steel Wks., Buffalo, N. Y.	Nov. 3, 1897
WINN, WALTER SCOTT	P. O. Box 137, Chattanooga, Tenn	Sept. 6, 1897

JUNIORS.

AURYANSEN, FREDERICK	Athens, Pa	Sept. 5, 1897
BELZNER, THEODORE	135 West 67th St., New York City	Sept. 5, 1897
CHASE, RICHARD DAVENPORT	15 Monroe Place, Brooklyn, N. Y	Sept. 5, 1897
HILL, CURTIS	Care of Deep Waterways Comm., North Tonawanda, N. Y	Sept. 5, 1897
HOUSTON, GAVIN NELSON	Asst. Engr., Nyack Water Works, West Nyack, N. Y.	May 4, 1897

CHANGES AND CORRECTIONS.

MEMBERS.

AUCHINCLOSS, WILLIAM S.	Bryn Mawr, Pa.
BISSELL, FRANK EDWARD	Asst. Engr., Wheeling and Lake Erie Ry., 434 Spitzer Bldg., Toledo, Ohio.
GUTHRIE, EDWARD BUCKINGHAM	Chf. Engr., Grade Crossing Comm., 4 Municipal Bldg., Buffalo, N. Y.
HUNT, CHARLES WARREN	Secretary Am. Soc. C. E., 220 West 57th New York City.
JAQUES, WILLIAM HENRY	Pres. The John P. Holland Torpedo Boat Co., 11 Broadway, New York City.
McMINN, THOMAS JAMES	220 West 57th St., New York City.
MALTBY, FRANK BIERCE	U. S. Asst. Engr., 2902 Ellendale Ave., St. Louis, Mo.
MASTEN, CORNELIUS STEWART	Charleston, W. Va.
NICOLLS, WILLIAM JASPER	Gen. Mgr. Flemington Coal and Coke Co., 210 Betz Bldg., Philadelphia, Pa.
NORTH, EDWARD P.	220 West 57th St., New York City.
OTIS, GEORGE ELLISON	Chf. Engr. Shreveport & Red River Val. Ry., Shreveport, La.
STEPHENS, CLINTON F.	Mine La Motte, Mo.
TALBOT, ARTHUR NEWELL	Prof. Municipal and San. Engineering Univ. of Illinois, 1011 California Ave., Urbana, Ill.
THOMSON, T. KENNARD	133 Park Hill Ave., Yonkers, N. Y.

ASSOCIATE MEMBERS.

BARNEY, SAMUEL EBEN, Jr.	503 Orange St., New Haven, Conn.
BROOKS, JOHN PASCAL	Box 843, Lexington, Ky.

Brownell, Ernest H............Care of Col. William Ludlow, Army Bldg., New York City.
Chibas, Eduardo Justo..........Care Am. Soc. C. E., 220 West 57th St., New York City.
Cosmus, John Albert............Care of Continental Ins. Co., Rialto Bldg., Chicago, Ill.
Creuzbaur, Robert Walter......Asst. Engr., Dept. Public Works, 150 Nassau St., New York City.
Cummings, Robert Augustus.....2119 Green St., Philadelphia, Pa.
Ferguson, Hardy Smith.........Lewiston, Me.
Himes, Albert James............Asst. Engr., N. Y. State Canals, Oswego, N. Y.
Stanford, Homer Reed..........Alton, Ill.
Tait, John George..............Res. Engr., Eastern Div., N.Y. State Canals, Albany, N. Y.
Towson, Morris Sherman ....63 Euclid Place, Cleveland, Ohio.
Van Ornum, John Lane..........Care of Brown, Shipley & Co., London, E. C., England.
Villalon, José R................Care of Am. Soc. C. E., 220 West 57th St., New York City.
Wilcox, Fred Elmer........... 309 Sterling Place, Brooklyn, N. Y.
Wright, Joseph Bodine..........424 West 23d St., New York City.

ASSOCIATES.

Abbott, Edward Lorenzo........16 West 99th St., New York City.
Futami, Kyosaburo..............Prof. of Civil Engineering, Kyoto Imperial University, Kyoto, Japan.
Warder, John Hainer...........1831 Arlington Place, Chicago, Ill.

JUNIORS.

Burns, James Ferguson..........Asst. Engr. L. & N. R. R., Hopkinsville, Ky.
Hopkins, Albert Lloyd..........U. S. Naval Academy, Annapolis, Md.
Howe, Horace Jos...............Chestnut St., Medford, Mass.
Hoyt, John T. Noye.............26 West 50th St., New York City.
Latting, Benjamin Franklin.....323 Second St., Brooklyn, N. Y.
Pegram, Walter Moray.........61 East 65th St., New York City.
Tappan, Roger..................152 Huntington Ave., Boston, Mass.
Sirrine, Joseph Emory.... ......Care of Indian Head Mills of Alabama, Cordova, Ala.

DEATHS.

Doane, Thomas................. Elected Member June 7th, 1882; died Oct. 22d, 1897.
Duane, James C................Elected Honorary Member. Nov. 20th, 1886; died Nov. 8th, 1897.

ADDITIONS TO

LIBRARY AND MUSEUM.

From American Society of Mechanical Engineers:
Eighteenth Catalogue of Officers, Members and Rules, July 1st, 1897.

From the Atchison, Topeka and Santa Fé Railway Company:
Second annual report of the company for the year ended June 30th, 1897.

From E. Bernard et Cie., Paris, France:
Notes et Formules de l'Ingénieur, du Constructeur-Mécanicien, du Metallurgiste et de l'Electricien.

From William Cain:
Theory of Voussoir Arches.
Maximum Stresses in Framed Bridges.

From F. A. Calkins, Chicago, Ill.:
Mayor's Message and Twenty-first Annual Report of the Department of Public Works of Chicago, Ill.

From Mendes Cohen, Baltimore, Md.:
Report of the Sewerage Commission of the City of Baltimore.

From F. P. Davis, New York:
Report of the Nicaragua Canal Board, 1895.
Hearings on House Bill 35 (on the Nicaragua Canal) before the Committee on Interstate and Foreign Commerce, House of Representatives.

From Leopold Eidlitz, New York City:
The Educational Training of Architects.

From the Field Columbian Museum:
Second Annual Exchange Catalogue, for 1897-98.

From the Frank-Kneeland Machine Co., Pittsburg, Pa.:
Illustrated Album of Lathes, Planers, Shears, Mills, etc.

From J. H. Fuertes, New York:
Water and Public Health.

From the Glasgow Philosophical Society of Glasgow:
Proceedings, Vol. XXVIII, 1896-97.

From Edward B. Guthrie, Buffalo, N. Y.:
Annual Report of the Department of Public Works of the City of Buffalo, N. Y., for 1896.

From Rudolph Hering, New York:
Die Müllverbrennungs-Versuche in Berlin.
Report on a Future Water Supply for the City of Winnipeg, Man.
Report on the Main Sewerage of the City of Ottawa, Canada.

From the C. W. Hunt Co.:
Steam and Electric Hoisting Engines.

From the Institution of Civil Engineers:
Minutes of Proceedings, Vol. CXXIX, 1896-97. Part III.

From the Institution of Junior Engineers:
Record of Transactions, Vol. VI, 1895-96.

From the Institute of Marine Engineers, Stratford, England:
Eighth Annual Volume of Transactions, Session, 1896-97.

From Imperial University, Tokyo, Japan:
Calendar for 1896-97.

From E. H. Keating, City Engineer, Toronto, Ont.:
Annual Report of the City Engineer of Toronto for 1896.

From A. Lietz Co., San Francisco:
The Cyclotomic Transit.

From Massachusetts State Board of Health:
Twenty-eighth Annual Report of the Board for the year ending September 30th, 1896.

From Smithsonian Institution, Bureau of Exchanges:
Annales des Travaux Publics de Belgique, Deuxième Série, Tome II. 4e Fascicule. Aôut, 1897.

From the State Agricultural College, Fort Collins, Colo.:
Bulletin No. 39. A Study of Alfalfa and some other Hays.
Bulletin No. 40. Barley.

From Lorrin A. Thurston:
A Handbook on the Annexation of Hawaii.

From U. S. Dept. of State:
General Index to Monthly Consular Reports, Nos. 152 to 203, Vols. 42 to 54.

From U. S. Navy Department:
Notes on Naval Progress, July, 1897.

From U. S. War Department:
Survey of Outer Bar of Brunswick, Ga. (in Duplicate).
Preliminary Examination for a Ship Canal from the Great Lakes to the Navigable Waters of the Hudson River (in Duplicate).

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

CONTENTS:

A PROBLEM IN CONTINUOUS ROPE DRIVING.

BY SPENCER MILLER, M. AM. SOC. C. E.

TO BE PRESENTED DECEMBER 15TH, 1897.

Much valuable literature has already been given to the engineering world on the subject of rope driving, and it is not the author's intention to review the subject generally, but merely to call attention to the perplexing problems which occur in driving with ropes, where the driving and driven sheaves are of unequal diameters, and especially where the driving wheel is the larger ; as, for example, in the dynamo drive. It is acknowledged that in such drives, as usually installed, where the ropes are applied as one continuous rope with tension carriage, they will not pull equally, and, as a result, a few of them do the major part of the work, and consequently it is now recognized that a factor of safety of from 30 to 40 is necessarily employed to cover the inequality of tension, imperfections in mechanism, weakness due to grease, splice, etc.

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

The author is satisfied that while by the usual method of figuring a factor of safety of 30 apparently is employed, he may be able to prove that frequently the actual factor of safety is not more than 15.

In considering the problem of rope driving, it is well to bear in mind the following undisputed facts :

First.—For efficiency in rope driving, it is absolutely necessary to increase the driving power of the rope by making angular grooves in the pulleys, the common practice being to make the angle 45 degrees.

Second.—The driving power of the rope increases rapidly as the arc of contact is increased ; for example, the relative power of an arc of 120° is only 75% of that represented by 180 degrees.

Third.—The greater the angle of incline of the grooves, the less will be the wear of the ropes ; the loss of power due to the pulling out of the rope from the groove will also be reduced. This loss, however, is not appreciable.

Hence, in designing a rope drive of the character under consideration, the first thing to determine is the sharpest angle of groove permissible for efficiency and wear of rope ; assume, then, that 45° is to be adopted as the minimum angle of groove, especially as this accords with the judgment of a majority of engineers.

Given, therefore, the smaller pulley with its smaller arc of contact grooved to 45°, the larger pulley may with its greater arc of contact have a greater angle of groove, without losing driving effect, and therein is a saving, for with the wider angle of groove, the rope wears less, and there is less loss of power due to the pulling of the rope out of the groove.

In a transmission of this character, if the arc of contact of the small pulley is 150°, and of the large pulley 210°, and assuming a coefficient of friction of .12, the angle of the small pulley being 45°, then the proper angle for the large pulley would be about *65° for equal adhesion on both wheels. Such transmissions are of very common occurrence.

Assuming, therefore, that the ropes are uniform throughout, it is found that :

By widening the groove of the larger pulley, the loss of power may be minimized, the life of the rope prolonged, and at no additional expense either for sheaves or loss of driving effect.

* See p. 523.

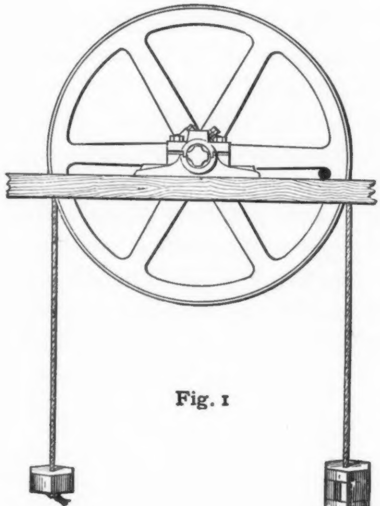

Fig. 1

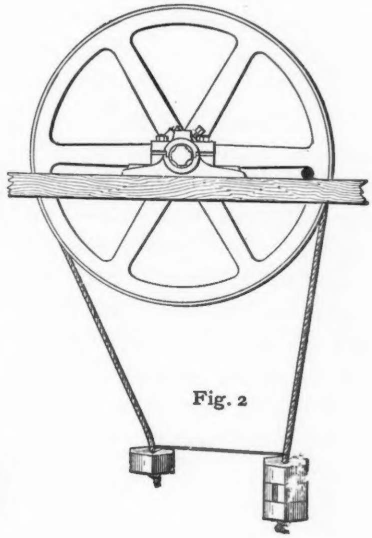

Fig. 2

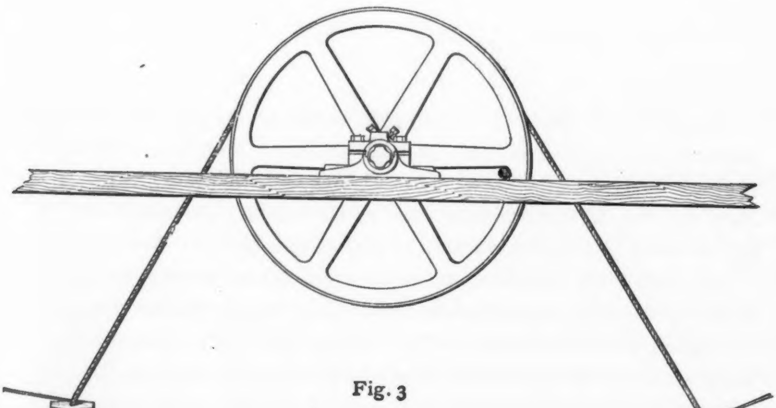

Fig. 3

The author will now attempt to prove that with the continuous rope plan of driving, and with the same strain on the driving rope, a large increase of power transmitted is obtained.

Before proceeding, it is well to review the elements, or the elementary part of rope driving, so as to clearly fix in one's mind exactly what takes place in each of the ropes in driving.

For instance, in imagination, try a few simple experiments: Mount a sheave wheel suitable for rope driving, grooved to 45°, so that it cannot revolve; place in the groove a short piece of rope having on one end, say, a 10-lb. weight; then put on the other end weights until the rope is just ready to slip (see Fig. 1). It may be that the 10-lb. weight will support 25 or 30 lbs., or even 50 lbs., in proportion to the coefficient of friction. The arc of contact in this case is 180°, or one-half the circumference. Assume—for it answers all the purposes of this discussion—that 10 lbs. support 25 lbs.; in other words, the ratio is as 10 : 25, or as 1 : $2\frac{1}{2}$.

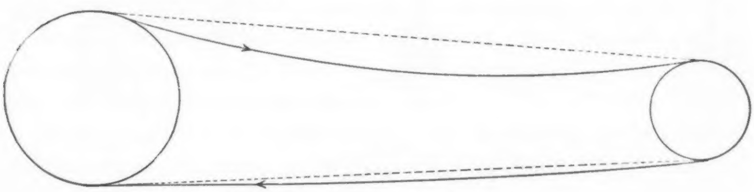

FIG. 4.

If now (by the use of a cord) the ropes are drawn together, so as to embrace, say, 220° of contact, it will be found that the 10 lbs. will support 30 lbs. (see Fig. 2). In other words, the ratio is as 1 : 3. Then try the third experiment, that of diminishing the arc of contact, say, to 140°, and the ratio becomes 1 to 2 (see Fig. 3).

In a rope drive, the part of the rope representing that supporting the 10 lbs. is the slack strand, while that supporting the greater weight is the driving side, or the tight strand of the rope. The tendency of the heavy weight is to revolve the wheel in its direction, and the measure of its effective pull is found by subtracting the pull on the tight side from the pull on the slack side; in other words, as in the first experiment, where the arc of contact is 180°, the tendency of the 10 lbs. is to pull in one direction, while that of the 25 lbs. is to pull in the other direction, and the effective pull is 25 — 10 = 15 lbs.

The fourth experiment will be to place side by side two sheaves of different diameters, having the same form of groove. Assume that one is 72 ins., and the other 36 ins. in diameter.

If, now, the first experiment is tried with each of these, it will be noticed that 10 lbs. supports 25 lbs., whether the ropes be applied to the 72-in. or the 36-in. sheave. These experiments show that the arc of contact is an important factor in designing a rope drive, and is independent of the diameter of the pulley.

The next matter of importance is to determine what takes place when motion is given to a rope drive.

Fig. 4 shows the simplest kind of a transmission, that of two grooved wheels and a single rope wrapped about them. When motion takes place and a load is given to the driven wheel, the lower strand straightens up and becomes taut, and the upper strand

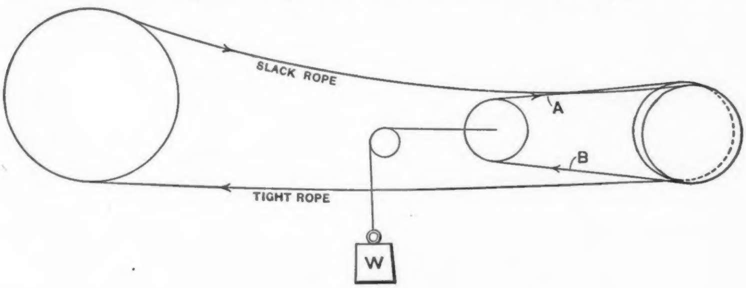

FIG. 5.

takes the slack from the driver in the direction in which the rope travels.

If the slack strand is sufficiently heavy, and is drawn up sufficiently taut, it will do the required amount of work. If it is desired to increase the work done by this rope, its tension must be increased. Suppose, therefore, that a loose sheave is added to the side of the driven wheel, and that a traveling idler, held back by a constant weight, as shown in Fig. 5, is put in, then it will be seen that the rope A is the slack rope, governing the tight rope (the lower strand), and the amount of tension permissible on the tight rope is determined by the tension on the rope A.

If the weight on the tension carriage is 150 lbs., then that on the rope A is 75 lbs. (neglecting friction), and with the ratio of slack to tight of 1 to 2, the pull on the tight rope will be 150 lbs. The tight

rope will, therefore, throw its slack to the upper strand, which in turn will be at once taken out by the rope B, whose tension is constantly 75 lbs. This tension in the slack strand is more than sufficient to sustain the tight rope, because, on account of the large arc of contact in the driver, the ratio is, say, 1 to 3. Hence, the rope will not transmit more power than the small pulley is capable of taking, and the slack is taken out by the tension carriage in the direction in which the rope travels.

In order to appreciate the effect of the loose single-grooved sheave, imagine, in Fig. 5, that a two-grooved driven sheave is used. Then, with a weight of 150 lbs. on the tension carriage, the tension on A and B would be 75 lbs. each. The tension in the upper strand would therefore be only one-half of that on B, because the rope B, drawing

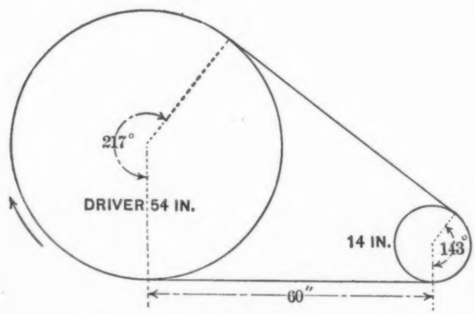

FIG. 6.

through the fixed groove in the driven would only affect the upper strand in the ratio of 2 to 1, and hence would be $37\frac{1}{2}$ lbs. The tension permissible in the lower strand cannot exceed three times the strain on the upper strand, because the traction ratio of the large pulley is 1 to 3.

Hence the tension on the pulling rope (lower strand) would be $37\frac{1}{2} \times 3 = 112\frac{1}{2}$ lbs.

Thus the driving pulley can only pull $112\frac{1}{2}$ lbs. when a two-grooved pulley is used, while with a loose wheel by the side of the driven, 150 lbs. can be sustained.

It is also worthy of notice that the slack strand governs only the amount which may be pulled by the large wheel, while the tension rope A governs what the tight rope may pull on the circumference of the small or driven wheel.

It is to be supposed that the reader is fully aware of all the points which have been reviewed, and they are only given here to direct his mind to further thought in this direction. An example in actual practice will be used to assist in further explanation.

A rope drive (Fig. 6) installed a few years ago had a driver which was 54 ins. diameter, and made 320 revolutions a minute; the driven was 14 ins. diameter, and made about 1 200 revolutions a minute. There were five strands of $\frac{3}{4}$-in. rope. Both wheels were grooved to 45°, and the distance between centers was 60 ins. By laying this out, it is found that the arc of contact on the large wheel is 217°, while on the smaller one it is 143° (see Fig. 6). This plant, after running a year, proved to be a failure, because, as the engineer said, "the rope would

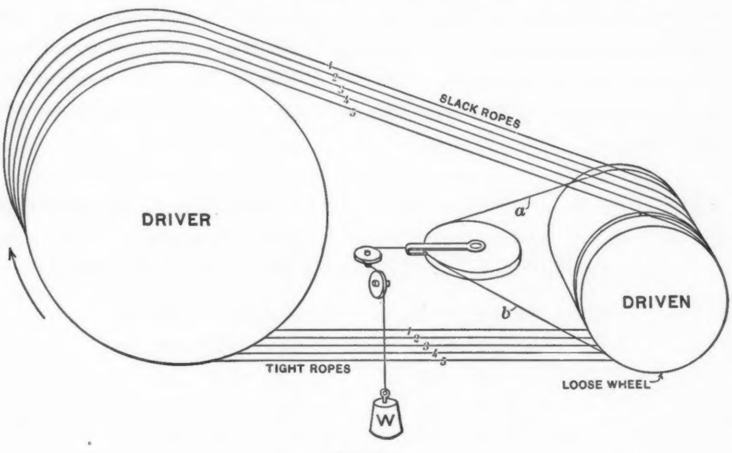

FIG. 7.

break frequently." He said, as he looked at the drive, he could see that "one or two ropes were doing the whole work."

Fig. 7 shows the way in which the ropes were led. Assume a tension weight of 300 lbs. Taking a coefficient of friction of .12, it is augmented by the 45° angle to .31.* Taking into account the arc of contact, the ratio of the slack to the tight side is therefore 1 to 2.12† on the small wheel, and 1 to 3.12 on the large wheel. For the sake of easy calculation omit the fraction and consider a traction ratio

* (Coef. of resistance to slipping $=$ Cosec $\frac{\text{angle}}{2}$ $\times$ coef. of friction.)

† See Table No. 6, p. 524.

of 1 to 3, and 1 to 2, respectively, in the large and small pulleys, and omit the weight of rope. Now imagine the engine starting, a full load of 50 H.-P. demanded on the part of the driven wheel, and trace what takes place. The rope *a* is held under a constant tension of 150 lbs. (half the weight on the tension carriage), with a traction ratio of 1 to 2 (slack to tight rope); the tight rope *1* will pull 2 × 150 = 300 lbs., the slack rope *1* will not sustain this pull of 300 lbs. until the tight rope *2* has been drawn through its groove in the small pulley and until the strain (in the slack rope *1*) is $\frac{1}{3}$ or 100 lbs. This slipping will continue until the tight rope *2* has a strain of 200 lbs. This rope will not slip further, because the strain of 200 lbs. is entirely used up when it meets in the slack rope *1* a resistance of 100 lbs. The slack rope *1*, being shortened up to have a tension of 100 lbs., will only allow the tight rope *2* to pull 200 lbs.; and following the same line of reasoning, the results in the following table are obtained (the slack passing out in the direction of the travel of the rope until the tension carriage takes it up).

TABLE No. 1.—Strains in the Various Ropes While Transmitting 53.5 H.-P., Neglecting Friction Losses, Weight of Rope, and Centrifugal Force. Both Wheels Grooved to 45° Angle:

Tight rope	*1*—300 lbs.	Slack rope	*1*—100 lbs.
"	*2*—200 "	"	*2*— 66 "
"	*3*—133 "	"	*3*— 44 "
"	*4*— 88 "	"	*4*— 30 "
"	*5*— 60 "	"	*5*—150 "
	781 lbs.		390 lbs.
	390 "		
	391 lbs. effective pull.		

Tight rope *5*, given as 60 lbs., may be raised somewhat by the influence of slack rope *5*, given as 150 lbs., as will be explained further on.

By taking the sum of all these tight ropes, a total of 781 lbs. is obtained, and the sum of all the slack ropes is 390 lbs., making a difference of 391 lbs. of useful work.

$$\frac{391 \text{ lbs.} \times 4\,518 \text{ ft. per min.}}{33\,000} = 53.5 \text{ H.-P.}$$

Assume the ultimate strength of $\frac{3}{4}$-in. rope to be 4 200 lbs., and in this transmission there is a maximum strain of 300 lbs., which gives an actual factor of safety of only 14.

If now the large wheel (Fig. 8) be grooved to 72°, so as to make the ratio 1 to 2 in each wheel, and the tension weight be reduced to 150 lbs., the result will be perfectly plain by again tracing the strains in the rope.

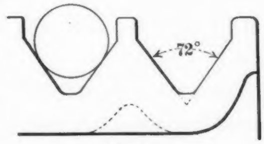

Fig. 8.

If a tension weight of 150 lbs. on the tension carriage be assumed, then there would be 75 lbs. tension on the rope *a*, which would give 150 lbs. tension to tight rope *1*, which cannot be sustained until there is 75 lbs. tension on the slack rope *1*, etc., each rope in itself being pulled at the rate of 150 lbs., and each slack rope 75 lbs., making the table appear like this :

TABLE No. 2.—Strains in the Various Ropes While Transmitting 50 H.-P., Neglecting Friction Losses, Weight of Rope, and Centrifugal Force. Large Pulley Grooved to 72°, Small Pulley to 45 Degrees.

Tight rope	*1*—150 lbs.	Slack rope	*1*—75 lbs.
"	*2*—150 "	"	*2*—75 "
"	*3*—150 "	"	*3*—75 "
"	*4*—150 "	"	*4*—75 "
"	*5*—150 "	"	*5*—75 "
	750 lbs.		375 lbs.
	375 "		
	375 lbs. effective pull.		

A total strain of 750 lbs. for the tight ropes, and 375 lbs. for the slack ropes, the difference being 375 lbs., which is sufficient for 50 H.-P. The maximum strain is now only 150 lbs., or one-half of that in Table No. 1; hence the factor of safety is 28.

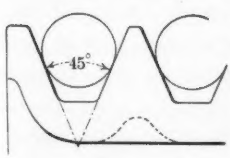

Fig. 9.

If, however, the same weight as in Table No. 1 is retained, viz., 300 lbs., the result will be as shown in Table No. 3.

TABLE No. 3.

Tight rope	*1*—300 lbs.	Slack rope	*1*—150 lbs.
"	*2*—300 "	"	*2*—150 "
"	*3*—300 "	"	*3*—150 "
"	*4*—300 "	"	*4*—150 "
"	*5*—300 "	"	*5*—150 "
	1 500 lbs.		750 lbs.
	750 "		
	750 lbs. effective pull.		

$$\frac{750 \text{ lbs.} \times 4\,518 \text{ ft. per min.}}{33\,000} = 100 \text{ H.-P.}$$

Thus it appears that the effective pulling power of the large wheel is actually reduced by reducing its angular groove, and at the same time the driving effect of the transmission is nearly doubled—a sort of mechanical paradox. Assuming again that the rope is uniform, it is found that by widening the groove of the large pulley the power transmitted is actually increased.

The question naturally arises : How account for the fact, frequently observed, that it is the center strands that are usually slack ? This can be explained as follows : The tension in slack rope *5* is given in Table No. 1 at 150 lbs., which may (if the power demands it) sustain $150 \times 3 = 450$ lbs. on tight rope *5*, but it will not do so until slack rope *4* is drawn out to a tension of $450 \div 2 = 225$ lbs., which is possible. If now, however, still more power is called for, then 225 lbs. on slack rope *4* may sustain a pull of 675 lbs. on tight rope *4*, which will draw up slack rope *3* to 337 lbs. This, however, is bad practice, because the maximum tension is increased far beyond 300 lbs., even in tight rope *5* pulling its maximum (450 lbs.).

On the other hand, if the loose wheel by the side of the small pulley were not used, the strain in slack rope *5* would be only 75 lbs., and the ultimate strain in tight rope *5* would be 225 lbs., and in slack rope *4* it would be 112 lbs. This shows that unless the wide angle is employed in the large pulley, it is better not to employ a loose sheave; all of which illustrates more forcibly the difficulties which accrue from the use of a uniform groove in both large and small wheels.

Further, it will be observed in Table No. 1 that the tension in slack rope *5* (150 lbs.) is $2\frac{1}{2}$ times as great as in tight rope *5* (60 lbs.),

while with the wide angle plan, as shown in Table No. 2, the tension in slack rope *5* is half of that in tight rope *5*, as it should be.

The practical value of this system, therefore, is to increase the factor of safety, or else by employing the same factor of safety to reduce the size of rope. Thus, when the difference in the diameters is considerable, substitute $\frac{7}{8}$-in. rope where previous figuring has shown that $1\frac{1}{4}$-in. rope was required; substitute for 1-in. $\frac{3}{4}$-in., and in place of $\frac{7}{8}$-in. use $\frac{5}{8}$-in.

The reduction in the size of the rope permits also a reduction in the diameter of the pulley, and still maintains the same ratio of rope to pulley. For example, the minimum diameter of the pulley for a $\frac{7}{8}$-in. rope is 35 ins., assuming the rule of 40 diameters, while for $1\frac{1}{4}$-in.

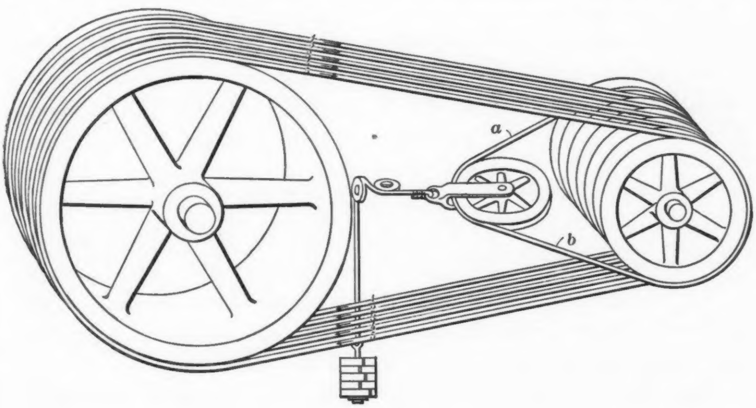

FIG. 10.

rope by the same rule a 50-in. pulley would have to be used. Then, again, the width of the sheave is thus reduced fully 25 per cent. It is not the author's intention, however, to advise employing a small factor of safety, but, by correct figuring, to obtain the real factor of safety, which should not be less than 20.

A full discussion of this question of proportions of rope to pulley may be found in "Rope Driving" by Professor Flather.*

The author's attention was originally called to this unequal tension on the ropes of a continuous rope drive some ten years ago. At that time he had occasion to study the subject, and was much puzzled by a drive installed with wooden sheaves. This particular transmission

* "Rope Driving." By John J. Flather, Ph. B., M. M. E., page 177.

had a driving pulley of about three times the diameter of the driven, and both wheels wore badly in the grooves. The first groove wore down fully an inch; the second, $\frac{3}{4}$ in.; the third, about $\frac{1}{2}$ in., and so on.

In another rope drive in the same building, also having wooden sheaves, but of equal diameter, the grooves wore alike. Hence, the natural conclusion that the unequal wear was attributable in some way to the unequal arc of contact occurring in the drive with pulleys of different diameters.

The substitution of iron sheaves for wooden ones prevents this object lesson from being brought to every one's attention, but the unequal strains on the various strands are there, just as before, and frequently can be seen if one will notice the difference in the sag of the various ropes.

As a practical proof of the value of the variable grooves, the author would refer to a rope drive designed by him some nine years ago, and installed in the planing mill of J. K. Russell, now called the Enterprise Building, on Fulton Street, Chicago, where they have been transmitting 250 H.-P. with 12 strands of $\frac{7}{8}$-in. ropes, which lasted six years. According to the present practice $1\frac{1}{4}$-in. rope would be employed (see Fig. 10). A 14-ft. driver is grooved to an angle of 60°, and a 6-ft. driven to 45 degrees. The ropes may be seen to be pulling alike, and each is doing its own share of the work.

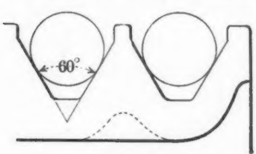

FIG. 11.

The calculations and tables given herein have ignored centrifugal action and journal friction, and are based on the assumption that the rope is uniform throughout, and further, that a loose wheel is provided to take the strand from the tension carriage leading from the pulling side of the driven wheel.

Flather's "Rope Driving"* gives a theoretical discussion of this very important matter, from which the following abstract has been prepared:

The effectiveness of the frictional grip is dependent upon the arc of contact of the rope with the pulley and also upon the coefficient of friction, which varies with the angle of the groove. The friction on each pulley will be the same if the products of the arcs of contact by the respective coefficients are equal. If the coefficient of friction of a

* Pp. 159 to 176.

lubricated rope on a smooth, flat metal pulley is 0.12, then, for the same rope, in a groove having an angle of θ degrees, it would be $\phi =$ $0.12 \operatorname{cosec} \frac{\theta}{2}$; hence, with arcs of contact of a and a' degrees the equations $\phi a = \phi' a'$, or $0.12 \operatorname{cosec} \frac{\theta}{2} a = 0.12 \operatorname{cosec} \frac{\theta'}{2} a'$ would indicate an equal frictional grip on each pulley, if it be assumed that the percentage of slip is to be the same, and that the multiplier 0.12 will give the correct coefficient of friction on each pulley.

The numerical value of the cosecant of an angle varies inversely with the angle, hence the pulley having the lesser arc of contact should have a groove with a more acute angle.

From the above equation

$$\operatorname{cosec} \frac{\theta}{2} = \operatorname{cosec} \frac{\theta'}{2} \times \frac{a'}{a}$$

in which θ and a are the angles of groove and contact, respectively, of the larger pulley; and θ' and a', similar values for the smaller pulley.

When the ratio of the arcs of contact is known and with the least angle of groove in the smaller pulley equal to 35°, 40°, or 45°, the corresponding angle of groove in the larger pulley should be as indicated in Table No. 5.

TABLE No. 5.—ANGLE OF GROOVE FOR EQUAL ADHESION.

$\frac{\text{Arc of contact on small pulley}}{\text{Arc of contact on large pulley}} = \frac{a'}{a}$	0.9	0.8	0.75	0.7	0.65	0.6
Angle of groove in large pulley when groove in small pulley = 35°	40°	44°	47°	51°	55°	60°
Angle of groove in large pulley when groove in small pulley = 40°	45°	50°	54°	58°	64°	70°
Angle of groove in large pulley when groove in small pulley = 45°	50°	55°	60°	66°	72°	80°

An equality of grip on each pulley may be secured by the use of an idler or binder pulley, which will increase the arc of contact on the smaller pulley, but this introduces a reverse bend in the rope, which is objectionable in rope driving and should be avoided as much possible.

The table on page 524 gives the amount of tension which may be sustained by the tight strand when the slack strand has a tension of one:

TABLE No. 6.

Degrees.	Coefficients of Friction.			Degrees.	Coefficients of Friction.		
	0.3.	0.4.	0.5.		0.3.	0.4.	0.5.
30	1.17	1.23	1.29	150	2.19	2.85	3.70
45	1.26	1.37	1.48	165	2.37	3.16	4.21
60	1.37	1.52	1.69	180	2.56	3.51	4.81
75	1.48	1.69	1.92	195	2.77	3.90	5.48
90	1.60	1.87	2.19	210	3.00	4.33	6.25
105	1.73	2.08	2.50	240	3.51	5.34	8.12
120	1.87	2.31	2.85	270	4.11	6.59	10.55
135	2.03	2.56	3.24	300	4.81	8.11	13.70

Vol. XXIII. DECEMBER, 1897. No. 10.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

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Vol. XXIII. DECEMBER, 1897. No. 10.

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INSTITUTED 1852.

PROCEEDINGS.

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CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

December 1st, 1897.—The meeting was called to order at 20.15 o'clock, Vice-President William R. Hutton in the chair; Charles Warren Hunt, Secretary, and present, also, 93 members and 16 visitors.

The minutes of the meetings of November 3d and 17th, 1897, were approved as printed in *Proceedings* for November, 1897.

A paper by William Cain, M. Am. Soc. C. E., entitled "Theory of the Ideal Column," was presented in abstract by the Secretary, who also read correspondence on the subject from Messrs. J. B. Johnson, A. Marston and Henry S. Prichard.

The Secretary announced the receipt of the following communications:

CHICAGO, ILL., November 17th, 1897.

CHARLES WARREN HUNT, Esq.,
Secretary American Society of Civil Engineers,
127 East 23d Street, New York City.

DEAR SIR,—The undersigned members believing that it is desirable that one of the two representatives on the Board of Direction from this district should reside in this locality instead of both living in the State of Michigan, hereby place Mr. Onward Bates, of this city, in nomination for Director in accordance with the provisions of the constitution.

CHARLES L. STROBEL.	IRA O. BAKER.
RALPH MODJESKI.	SAM'L P. ARTINGSTALL.
W. M. HUGHES.	ROB'T A. SHAILER.
EDW'D C. CARTER.	E. GERBER.
LOUIS H. EVANS.	CHAS. E. BILLIN.
M. LASSIG.	H. N. ELMER.
W. W. CURTIS.	HORACE E. HORTON.

CHICAGO, November 26th, 1897.

CHARLES L. STROBEL, C. E.,
Chicago, Ill.

DEAR SIR,—I shall be pleased to accept the nomination by petition for the office of Director in the American Society of Civil Engineers.

Yours truly,
ONWARD BATES.

Ballots were canvassed and the following candidates declared elected:

AS MEMBERS.

WILLIAM ETHELBERT BELKNAP, Brooklyn, N. Y.
AUSTIN LORD BOWMAN, New York City.
MARMADUKE WARD EASBY, Philadelphia, Pa.
EMIL EDWARD KUERSTEINER, Cincinnati, Ohio.

AS ASSOCIATE MEMBERS.

WERNER BOECKLIN, Jr., New York City.
RALPH HAMILTON CHAMBERS, Boston, Mass.
CHARLES ALBERT MCKENNEY, Washington, D. C.
GEORGE WHITFIELD SYKES, Mercer, Pa.
JOSEPH HARRISON WALLACE, Holyoke, Mass.
CHARLES WORTHINGTON, Pittsburg, Pa.

Adjourned.

December 15th, 1897.—The meeting was called to order at 20.20 o'clock, Edward P. North in the chair; Charles Warren Hunt, Secretary, and present, also, 91 members and 23 guests.

A paper entitled "A Problem in Continuous Rope Driving," by Spencer Miller, M. Am. Soc. C. E., was presented by the author and illustrated by the stereopticon. The Secretary read correspondence on the subject from Messrs. Samuel Webber and J. J. Flather. Oral discussion followed by Messrs. H. H. Suplee, H. W. Brinckerhoff, Joseph H. Hoadley and the author.

The Secretary made announcements relative to opening the Society House in the evenings and on Sundays and holidays (see page 188); also relative to the Annual Meeting.

The Secretary announced the election by the Board of Direction on December 7th, 1897, of the following candidates:

As Juniors.

Lee Highley, Clinton, Ill.
Thomas Dorsey Pitts, Tarpon, Tex.

The Secretary announced the deaths of the following members:

Thomas D. Leavitt, elected Member May 3d, 1871; died December 4th, 1897. Francis E. Prendergast, elected Member March 7th, 1888; died December 7th, 1897. Edwin D. Nourse, elected Member September 3d, 1884; died December 8th, 1897.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

December 7th, 1897.—Eleven members present.

The following resolution was passed:

"*Resolved*, that the House of the Society be hereafter open every day in the week until 22 o'clock with proper attendance, except Sundays, when the house shall be open only from 14 to 19 o'clock."

Applications were considered and other routine business transacted.

Two candidates were elected as Juniors.

FORMAL OPENING OF THE NEW SOCIETY HOUSE.*

The New House of the Society, No. 220 West Fifty-seventh Street, was formally opened on the 24th of November, 1897. From 9 until 14 o'clock the house was open for inspection by members and their friends.

The formal exercises, in the auditorium, beginning at 15.30, were presided over by President B. M. Harrod, and were opened with a dedicatory prayer by the Rt. Rev. Henry C. Potter, Bishop of the Diocese of New York.

Addresses were delivered by President Harrod, General William P. Craighill, J. G. Schurman, LL.D., and the Hon. Joseph H. Choate.

A congratulatory telegram from the Institution of Civil Engineers of Great Britain was received.

A resolution of thanks to the speakers and to the Institution of Civil Engineers was adopted.

In the evening, at 21 o'clock, there was a "House Warming."

Exact figures of the attendance were not kept; it is estimated that in the afternoon there were about 550, and in the evening about 700 present.

ANNOUNCEMENTS.

HOURS DURING WHICH HOUSE WILL HEREAFTER BE OPEN.

In accordance with the resolution of the Board of Direction the House of the Society will be open every day hereafter from 9 to 22 o'clock, except on Sunday, when the hours will be from 14 to 19 o'clock.

The continuance of this regulation must necessarily depend on the use made of the House by members, and it is hoped that the additional expenditure entailed by keeping the House open during the evenings and on Sundays and holidays will be justified by the future attendance.

INDEX FOR PROCEEDINGS.

The Index for the *Proceedings* for 1897, Vol. XXIII, will be issued with the *Proceedings* for January, 1898.

MEETINGS.

Wednesday, January 5th, 1898, at 20 o'clock, a regular meeting will be held, at which a paper by S. Bent Russell, M. Am. Soc. C. E., entitled, "Experience with a New Machine for Testing Materials by Impact," will be presented. It is printed in this number of *Proceedings.*

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* The addresses, in full, will be found in this number of *Proceedings.*

ANNUAL MEETING.

Wednesday and Thursday, January 19th-20th, 1898, the Forty-fifth Annual Meeting of the Society will be held. The Business Meeting will be called to order at 10 o'clock on Wednesday morning, when the Annual Reports will be read, officers for the ensuing year elected, and other business transacted.

Messrs. E. E. Olcott, S. L. F. Deyo, W. E. Belknap, A. S. Tuttle and Charles Warren Hunt have been appointed by the Board of Direction as a Special Committee of Arrangements, and a programme in detail is being prepared.

There will be a reception on either Wednesday or Thursday evening, and it is probable that, in accordance with the usual custom, the second day of the meeting will be devoted to an excursion to some point of interest. Ladies of the families of members will be welcome on the excursion and at the reception.

DISCUSSIONS.

Discussion on the paper by John C. Branner, Ph. D., entitled "Geology In Its Relations to Topography," which was presented at the meeting of November 17th, 1897, will be closed January 1st, 1898.

Discussion on the paper by William Cain, M. Am. Soc. C. E., entitled "Theory of the Ideal Column," which was presented at the meeting of December 1st, 1897, will be closed January 15th, 1898.

Discussion on the paper by Spencer Miller, M. Am. Soc. C. E., entitled "A Problem In Continuous Rope Driving," which was presented at the meeting of December 15th, 1897, will be closed February 1st, 1898.

ADDITIONS TO

LIBRARY AND MUSEUM.

From the American Institute of Mining Engineers:
- Genesis of Certain Auriferous Lodes.
- A New Form of Ingot-Mould for Casting Brass or Bronze Ingots.
- Calorific Value of American Coals.
- Influence of Lead on Rolled and Drawn Brass.
- Electrolytic Assay as Applied to Refined Copper.
- Biographical Notice of Peter Ritter von Tunner.
- Notes on Six Months' Working of Dover Furnace, Canal Dover, Ohio.
- Mining Methods on the Mesabi Range.
- Marquette Range. Its Discovery, Development and Resources.
- Investigations of Water Supply.
- Technology of Cement Plaster.
- Iron Ore Supply.
- Explorations on the Mesabi Range.
- Improvements in Mining and Metallurgical Appliances during the Last Decade.

From American Society of Mechanical Engineers:
- Transactions, 1897.

From Australasian Institute of Mining Engineers:
- Transactions, Vol. IV, 1897.

From Chamber of Commerce of Frankfort-on-the-Main:
- Reports for the Years 1895 and 1896.

From Chief of the Bureau of Steam Engineering:
Annual Report, 1897.

From George Earl Church, London, England:
A Railway Map of the Argentine Republic, 1897-98.

From B. W. Dunn, Philadelphia, Pa.:
Journal of the Franklin Institute for November, 1897.

From Flint, Eddy & Co., New York:
Book of Reference and Information on American Practice in Railroads, Lake and River Navigation, Public Works, Electrical Appliances and Special Industries.

From Charles Evan Fowler:
General Specifications for Steel Roofs and Buildings.

From Henry S. Haines:
American Railway Management.

From Alfred J. Henry, Chief, Division of Records, U. S. Weather Bureau:
Rainfall of the United States.

From Vl. Herzenstein, Directeur du Bureau Technique International:
Le Mécanisme du Lit Fluvial.

From E. W. Howe, Boston, Mass.:
Twenty-second annual report of the Board of Commissioners of the Department of Parks, Boston, 1897.

From Indiana Engineering Society:
Proceedings of the Seventeenth Annual Meeting, 1897.

From the Institution of Engineers and Shipbuilders in Scotland.
Transactions, 1896-97.

From Lehigh University, South Bethlehem, Pa.:
Probability of Hit When the Probable Error in Aim is Known; Past and Present Tendencies in Engineering Education.

From Liverpool Engineering Society:
Inaugural Address of the President, November 3, 1897.

From McGill University, Montreal:
Announcement of the Faculty of Applied Science for the Session, 1897-98.

From Merchant & Co., Philadelphia:
Trade Catalogue, 1897.

From National Brick Manufacturers' Association:
Report of the Commission appointed to investigate the Subject of Paving Brick Tests.

From Pratt Institute Free Library, Brooklyn, N. Y.:
Report for the year ending June 30th, 1897.

From Purdue Society of Civil Engineering, Lafayette, Ind.:
Proceedings, 1897.

From Eugène Rombaut, Bruxelles:
Rapport sur la Situation de l'Enseignement Industriel et Professionnel en Belgique; Années, 1884-1896.

From Society of Montana Pioneers:
Sketch of the Life of Walter Washington de Lacy.

From Students of Union College, Schenectady, N. Y.:
The Concordiensis, Vol. XXI, No. 9. 1897.

From U. S. Interior Department Geological Survey:
Water Supply and Irrigation Papers: No. 4, A Reconnoissance in Southeastern Washington by Israel Cook Russell; No. 5, Irrigation Practice on the Great Plains by Elias Branson Cowgill; No. 6, Underground Waters of Southwestern Kansas by Erasmus Haworth; No. 7, Seepage Water of Northern Utah by Samuel Fortier; No. 8, Windmills for Irrigation by Edward Charles Murphy; No. 9, Irrigation Near Greely, Colo., by David Boyd; No. 11, River Heights for 1896 by Arthur Powell Davis.

From United States Naval Institute:
Notes on the Yacht *Defender* and Use of Aluminum in Marine Construction.

From U. S. Navy Department:
Report of the Surgeon-General, 1897.

From U. S. War Department:
On the Perforation of Face-Hardened Armor.

From the University of the State of New York:
Extension Bulletin, May, 1897. Summer Schools.
Extension Bulletin, June, 1897. Public Libraries, No. 6.
State Library Bulletin, July, 1897. Bibliographies, Nos. 2-4.
Annual Report of the Regents, 1895. 2 vols.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CONTENTS:

ADDRESSES DELIVERED AT THE OPENING OF THE NEW SOCIETY HOUSE, NOVEMBER 24TH, 1897.

DEDICATORY PRAYER, BY RT. REV. H. C. POTTER.

Let us pray. Almighty and Everlasting God, who art always most ready to hear our petitions and art wont to give to us more than we can desire or deserve, we thank thee that thou hast taught us in thy holy Word to come to thee and to ask thy heavenly benediction upon all our human undertakings. We are here this afternoon to ask thy blessing upon this work, upon the crown of success which thou hast vouchsafed us to put upon it, and to beseech thee to take it into thy holy keeping and to make it useful for those great ends for which this institution stands. We bless thee for the revelation of thy law, as in Nature, so in thy holy Word. We bless thee that thou hast taught us how the forces of Nature may be harnessed by the ingenuity of man and made to do the service of man. We thank thee for the

triumphs of this union in all the history of the century in which we live, so various in its illuminating and transforming powers, so wonderful in its manifold illustrations of the word of thy revealed scriptures that "many shall run to and fro and that knowledge shall be increased," over the highways which have been built by the art of men, in which wisdom and light have gone all around the world and that the representatives of this institution, and those who are like-minded, have carried to the ends of the world that which has come from the lamp of the student and from the patient, constant and vigilant study and experiment of men who have discovered and settled the laws by which so largely to-day our great natural forces are harnessed and governed for the purposes of man. Grant, we pray thee, that the wonderful wisdom as thus wrought in thy universe may continue to work under thy divine and supervising guidance, and that all men everywhere to whom thou hast given the faculties of ingenuity, of contrivance, of study, the art of penetrating the secrets of thy Word, may be glad to use them in thy fear and to thy glory. We give this institution to-day and all who belong to it into thy holy keeping. We ask thy blessing upon its officers and upon all present, and we beseech thee that everyone here may recognize that in what he does for art, for science, for the upbuilding of material structures, he is thy servant in the use of thy divine forces to the glory of thy holy name. Remember our common country and all who rule over us. Remember all men everywhere who are striving out of the chaos of ignorance and waywardness and lawlessness to bring mind and heart and man into subjection to the higher law, and so finally to service to thee. And all this we ask in the name and for the sake of Him who has taught us when we pray to say: "Our Father, who art in heaven, hallowed be thy Name. Thy kingdom come. Thy will be done on earth, as it is in heaven. Give us this day our daily bread. And forgive us our trespasses, as we forgive those who trespass against us. And lead us not into temptation; but deliver us from evil: for thine is the kingdom, and the power, and the glory, forever and ever. Amen.

ADDRESS OF B. M. HARROD,

PRESIDENT, AM. SOC. C. E.

Ladies and Gentlemen,—I thank you, in behalf of the American Society of Civil Engineers, for the lustre and dignity which your presence gives to the dedication of this House, to the promotion of that learning and the encouragement of that professional and fraternal fellowship which are necessary to the growth and influence of the science of civil engineering.

Our intention in erecting this commodious building has not been limited to serving the close uses of a club, or even to providing a professional resort for our own members. We have been moved by larger aims, and have builded with the hope that we might greatly aid in promoting those objects of a National Society, and in supplying those wants of our profession which have been made prominent and important by the extent and direction of its evolution during the present generation.

The discovery of new forces in Nature, and the invention of new methods of their application to the uses of man, have so enlarged the field of civil engineering that neither the duration of human life nor the limit of human faculties serves for the acquisition of such a knowledge of the details of all of its branches as is sufficient to insure success in the practice of each or all of them. This condition and limitation of modern scientific learning has become so controlling that it is now necessary to prepare special courses of study, to confer special degrees, to form special social and professional organizations, and to establish a special press for the mechanical, the sanitary, the electrical, and other classes of civil engineers. Also the rapid expansion of our country, and the marvelous diversity of its topographical features, have in many cases and localities limited the practice of engineers to work in a single department, such as the improvement of rivers and harbors, municipal engineering, the extraction of ores and minerals, the irrigation of lands, and their protection from overflow. These tendencies, with the great intervening distances, involving time and expense, have made the opportunities of resort to a single center so infrequent and difficult, that the reasonable social and professional wants of the civil engineer have inevitably led to the formation of special or local societies.

The variation from which this evolution of the technical society has sprung is both natural and useful, and has contributed largely to the promotion of scientific learning, the efficiency of the profession, and the success of its members.

But while we recognize the obligations of the profession to the agencies to which I have alluded, the conviction still remains that they have not sufficed to bring its members into that social and professional fellowship which is the evidence of healthy growth, and the outward and visible sign of the unity of the scientific knowledge on which the best practice is based, and of the singleness of our ultimate aims; nor has their success been sufficient to give our profession a position in the public estimation, as both learned and responsible, the peer of law or medicine, to which it is entitled by the contributions it has made to the public wealth, happiness and safety, and which has been accorded to it in countries where the motives of specialization and the difficulties of general and personal association are not so controlling as they are here. Certainly the record of American civil engineering, in difficulty, in magnitude, in originality, in thoroughness, and in the opportunity it has given for the growth of the best civilization, is at least comparable to that of any country or age. Certainly the labors of the civil engineers in this country have contributed a share to its development and prosperity which has not been exceeded by any other class of her citizens.

It is worthy of consideration, whether in the diversity of study and work resulting from modern conditions, we are not losing sight of the essential unity of the profession, and of the truth that, while mining, sanitary, electrical or other lines of engineering may be differentiated in practice by the exigencies of the times, yet there is a science of civil engineering which is not only a remainder after these are taken away, but an organized body of correlated truths forming the roots and trunks of a great tree of knowledge of which these are but the branches. "It is not a mere juxtaposition of parts, but a complex organic whole, and its different departments are so closely allied that, without a general knowledge of all, it is impossible to have a complete comprehension of, or eminent success in, any."

With this view, the birth, the growth of every special or local society, and the expansion of the field of its labors, is but another reason for co-ordination, and the application of their accumulated influence and resources to a common purpose, to the promotion of learning and the prosperity of our profession, through the agency of a

single organization, in which they may all find representation and alliance.

It is fit that this unity and breadth of the science, and the interest of American civil engineering, should find an exponent in a National Society, where all engineering knowledge and all of its departments shall receive adequate consideration; where engineers from all parts of the country can meet for the formation of friendly ties or the exchange of professional views, and where measures for the promotion of the welfare of civil engineers and of civil engineering can be concerted with such full and impartial consideration of all of their aspects as will command national attention and respect.

Among the functions which have been or can be properly exercised by such a society for the increase of the dignity and strength and good-fellowship of the entire profession, I may mention the conventions now annually held in different parts of the country, both the social and professional results of which have been of much interest and value; also the appointment of select special committees for the examination of questions of material or method, concerning which practice is uncertain or unsettled; also the excursion of American Civil Engineers to the Paris Exposition, and other parts of Europe, in 1889; also the reception and entertainment of foreign engineers, the organization of the Engineering Congress and the publication of the *Transactions* of that Congress, on the occasion of the Chicago Exposition in 1893, from which sprung that most useful Society for the promotion of engineering education; also the timely presentation, by memorial and committee, of important subjects of applied science to the attention of Congress; also the publication of transactions by such a society, proportioned in range, in value and volume to its membership; also the collection of a comprehensive library, and the adoption of liberal rules for its use; and, I may add, the building of a House where all these plans may be considered and matured; where all recorded technical knowledge can be safely stored and made available; where civil engineers can meet to form and strengthen the ties which should bind professional brethren together; to seek, by reference or conference, such information as they may need for projected work, and to participate in or otherwise promote the dignity, the welfare and the pleasures of a professional life.

This Society stands for the increase of both general and special

scientific culture in civil engineering; for the extension of professional and personal fellowship, based on this general culture, among engineers engaged in any of its various branches, and in all parts of the country; and for such just increase in the standards, the dignity, the rights and the emoluments of the profession as may be expected to follow earnest and intelligent organization and co-operation. This House is dedicated to these uses.

It is not without a serious sense of responsibility that we introduce our Society to this new and enlarged stage of its life. In the past, since its birth in 1852, its growth in members, in resources and in good work, has been so rapid and uninterrupted as to vindicate the *raison d'être* of a National Association of Civil Engineers. It has acquired new strength by the use of its powers. But the anxieties of a new and larger life are on our shoulders, and we invoke and welcome the kind offices and interest of our friends. From our members we ask a vigilant and sustained interest in the objects and administration of the affairs of the Society; from their sweethearts and wives that they will exact a paper from their correlated members, and insist on attending the next Annual Convention; and from civil engineers and the enlightened public a serious consideration of the relation which the Society bears to the welfare of the profession and the progress of our country, and the service which it has already rendered, and can render, in an increasing degree, in the future.

Let me again thank you for the interest and good wishes which are expressed by your presence here to-day, and welcome you to our New Society House.

ADDRESS OF GEN. WILLIAM P. CRAIGHILL,

PAST-PRESIDENT, AM. SOC. C. E.

Mr. President, Ladies and Gentlemen,—I think myself fortunate in having the privilege in this public way to be able to congratulate the American Society of Civil Engineers upon the auspicious event which brings us together to-day, marking, as it does, a great step forward for the Society in material prosperity.

It has been suggested that it would be appropriate for me to speak from the standpoint of the military engineer. This I therefore do, and, following the very proper intimation contained in the invitation extended to me by the Committee of Arrangements, I will be brief.

What I shall say will be in the direction of indicating the influence upon the profession of civil engineering which has been exerted by the military engineers of this country and the reasons for it. In so doing I must necessarily refer to the Military Academy at West Point, and to the Corps of Engineers of the Army, and I trust to be excused if my words should be warm concerning the Alma Mater who gave me professional birth, and concerning my professional brothers in the Corps of Engineers, all her sons, with whom I have been associated for more than forty-four years in the service of our country.

First, it is true that the properly prepared military engineer must necessarily have also the general education of the civil engineer in the ordinary use of that term. In the structures he builds he is called upon to use all the materials, wood, earth, stone and metals which are found in the works of the civil engineer. The structures of the military engineer are peculiar in their forms and arrangements in order to suit them to their special functions. So far as their foundations and stability are concerned, under the various strains to which they are to be exposed, they must conform to the usual rules for civil works. But they are also liable to sudden and violent shocks from the impact of the huge missiles of modern war, which may strike them with their highest velocities, and special provision must be made to meet these special conditions. Therefore, at the Military Academy at West Point, the education, from its beginning to its close, leads one through text books on pure and applied mathematics, chemistry, mineralogy, draughting, surveying, the laws of civil engineering, and finally the specialty of military engineering.

In the earliest days of our country the engineer of any kind was hard to find. Many people suppose a man to be an engineer who is only a surveyor. An engineer should be conversant with the duties of the surveyor, but a man could be an excellent surveyor all his life and not be an engineer at all. Washington was a surveyor in his youth, and doubtless could have become a great engineer, but an inspection of the site of Fort Necessity, not far from Pittsburg, where he was forced to surrender to the French, would not lead one to conclude that he was well versed at that time in the art of the military engineer. He no doubt did the best that the circumstances permitted, many of which we do not know.

In the campaigns of the Revolutionary War, Washington felt the need of native military engineers, and was obliged to depend on foreigners, mainly Frenchmen. But among them was one distinguished Pole, Kosciusko, to whom a monument stands at this day at West Point, the scene of his labors in the defence of that important post, which Washington himself knew well and where he had his headquarters when the discovery of Arnold's treason occurred.

As early as October, 1776, a committee of the Continental Congress recommended that the Board of War be directed to provide a military academy, and this scheme was highly favored by General Knox, one of the leading military authorities of the time. General Washington never ceased during the war to call the attention of Congress to the importance of a systematic organization of the army and the education of its officers in scientific knowledge and for this reason he urged the establishment of a military academy. This he continued to do from the close of the war in 1783 to the end of his life in 1799.

The law of 1802 created a corps of engineers which, as its words state, "shall constitute a military academy." This law was approved by Jefferson as President, though he alone when a member of the cabinet of Washington had doubted in 1793 the constitutionality of a military academy. The academy was located at West Point, a place peculiarly fitted for such an institution.

We have now many most valuable technical schools, and several of them are not surpassed by any similar schools in the world. At these engineering is specially taught much more fully and extensively in all branches, except the military and naval, than is possible at West Point with its peculiar limitations, but the Military Academy at West Point

was the first school of engineering in this country and for a long time the only one. In the excellence of its methods and course of instruction it claims to have been progressive and to be now the equal of any school, so far as thoroughness goes, having in view the special duties to which its graduates are likely to be called.

But the Corps of Engineers of the Army is older than the Military Academy, inasmuch as General Washington was authorized December, 1776, to raise and collect for six months a corps of engineers; but for want of proper material in the country he could accomplish nothing. July 8th, 1777, several of the officers of the Royal Corps of French Engineers were commissioned. From the lack of trained engineers in the native continental establishment, their assistance was highly appreciated, and for many years this foreign influence predominated in the service. As late as 1816, a prominent French engineer was employed to assist in planning some of the defensive works of this country. He had served creditably on the staff of the great Napoleon. This was General Bernard. His views are largely exemplified at Fort Monroe, where he planned a kind of fortress somewhat after the European idea to which he was accustomed, but it is a style not in accordance with American ideas or institutions.

On March 11th, 1779, a corps of engineers was formally established, and its first chief was a Frenchman. In 1783, at the close of the war, this corps was disbanded. In 1794, a new organization was formed, including engineers and artillerists, which was modified by later and successive laws, until in 1802 the President was authorized to organize and establish a corps of engineers to constitute a military academy and to be stationed at West Point.

Beside the usual duties of military engineers, which are those of constructing temporary and permanent fortifications, military bridges and siege works, in making military reconnaissances and surveys, the preparation and use of mines and torpedoes in coast defence, etc., they have been called upon in time of peace to plan and execute works of river and harbor improvement, to build lighthouses, plan docks for the Navy, and to undertake and complete many other public works, such as the introduction of water into the City of Washington, the supervision of the construction of public buildings, such as the Washington Monument in Washington, the Capitol, the Post-Office Department, the Interior Department, the Smithsonian Institution, the New

Congressional Library, etc., to execute surveys for the transcontinental and other railways, to lay down boundaries, etc.

It is thus manifest that the military engineers have had a very great variety of duties, and the course of instruction at West Point has been such as would prepare the men as far as possible for the duties imposed upon them. A great number of civilians have been associated with the military engineers in their varied duties. While I held the office of Chief of Engineers, it was found that there were over five thousand men serving in the engineer department all over the United States, in the grades of engineer, surveyor, draughtsman, rodman, chainman, recorder, clerk, superintendent, inspector, overseer, pilot, etc., not including the still greater number of persons hired by contractors.

Many of these employees of the engineer department have become prominent as civil engineers, and much credit is due them for the results of their labors. No one is more anxious than I am to have them receive the credit which is their just due. A number of these men are now Members of this Society. I am sure that very much of any professional reputation I may have is due to the cordial, loyal and able assistance I have had from my subordinates, both in and out of the Corps of Military Engineers.

Many engineer officers have from time to time resigned and become distinguished as civil engineers, as teachers and otherwise. The superintendence of the construction of one of the greatest and earliest railroads in Europe, that between St. Petersburg and Moscow, was, from 1842 to 1849, in charge of Major Whistler, an American engineer.

The writings of some of the officers of the Corps of Engineers were standard authorities in their time ; for example, Wright, Totten and Gillmore, on mortars, limes, cement and concrete; Woodbury, on the arch; Halleck, on asphalts ; Sanders, on pile-driving; Mahan, on civil engineering, etc. The extensive use of asphalt and concrete in this country may be said to have originated with the Corps of Engineers on works of fortification. The superintendents and professors of the Military Academy have almost all been taken from the Corps of Engineers.

Here let me introduce some short extracts from the writings of another :

"Up to about 1831, the officers of the Corps of Engineers were to a great degree the repositors in this country of that knowledge which was requisite for the purpose of making accurate surveys. The location and construction of the roads, canals and bridges built for the development of the resources of the country, and the accurate methods of surveying, geodetic, topographic and hydrographic, now in use, are in a great measure due to the talents and labors of its officers.

"Very many of the great routes of internal communication in the interest of commerce and speedy transit, now in existence in the country, were first explored, located and projected by officers of this corps. The files of the bureau of the corps in Washington and the congressional documents are rich in reports upon the works of this character that have been examined into under authority of law by the Corps of Engineers.

"In the matter of improvement of rivers and harbors, in the interest of commerce, the Corps of Engineers has had almost the exclusive control, and the information on this subject contained in the reports of its officers, from the early years of this century to the present time, now filed in the bureau of the corps, is a monument to its labors, and a most valuable collection of precedents to be used in the future prosecution of such works.

"The surveys, examinations and constructions which have been made by officers of the corps, have not been confined to such matters as are solely in charge of the War Department. From time to time the State Department, the Navy Department, the Treasury Department and the Interior Department have employed its officers in the running of boundary lines, and the surveys for the maps necessary to be used in delicate diplomatic negotiations; in the surveys for, and the construction of, dock-yards; the surveys for canal routes across the Isthmus of Panama and elsewhere; upon astronomical observations in the interest of science; in the surveys of the coasts, the planning and construction of lighthouses and other fixed aids to navigation; the planning and construction of public buildings, of custom houses, post offices, marine hospitals, etc.

"Scarcely a branch of engineering, whether military or civil, can be mentioned that has not been improved and expanded by the study and labors of the officers of this corps.

"It is difficult to enumerate all the duties which may have been, or which can be devolved on the Corps of Engineers in time of peace. As the duties generally are such as require familiarity with the sciences and arts, any duty which the Government needs performed which involves the application of this character of learning, and comes within the professional training of the several members of the corps, may by law be devolved by the President upon them."

I think what has been said is a sufficient ground for the belief on my part, and its statement in this presence, that the education and discipline of West Point, supplemented by the methods used in the practice of the officers of the Corps of Engineers of the Army, have had a very great influence upon the profession of engineering in this country, and that influence has been to a very large extent beneficial and creditable.

In conclusion, Mr. President and brother engineers, I affirm that the profession of the engineer is one of the noblest and most useful which is open to man. It is also one of the most ancient. It is a curious historical fact that the title, Pontiff, of the head of the Roman Catholic Church, is derived from *pontifex maximus*, which means the chief bridge builder or engineer; and this was also the title of one of the most important functionaries of Rome long before the rise of the Christian Church, originating with Numa, and held by many of his successors.

I am proud to have been an engineer for nearly half a century, and I am proud now to be a member of this American Society of Civil Engineers. May her ends be always high, noble and honorable, and may membership in our society be always a guarantee of ability, honor and faithfulness in the performance of duty. It has been thought by some that we should have a written code of ethics for our guidance. I do not believe that such a code is necessary, provided we regulate our professional conduct by that rule which is able to cover every possible case between man and man, the Golden Rule, in its true, broad sense: Do to all men as you would have them do to you.

Before taking my seat I beg the indulgence of this body of engineers to refer to something in which every engineer is interested, and the military engineer in particular. It has been said by some that the peculiar duties of engineers in peace unfit them for the successful command of troops in the field. Let me state a few facts about this matter from our own history: When the late Civil War was closed, the Army of the Potomac, that magnificent body of veteran soldiers, was commanded by Meade, an ex-officer of the Corps of Engineers. Every corps in that army except the cavalry was also commanded by an officer of engineers. This was also true of two of the corps in the Army of the James, which co-operated with the Army of the Potomac.

McPherson, who fell at Atlanta, and Mansfield, who fell at Antietam, were two of the earliest brigadiers of the regular army in that war, and both came from the Corps of Engineers.

In two of the most critical and fiercely contested battles of the war, Antietam and Gettysburg, both armies were commanded by ex-officers of the Corps of Engineers; at Antietam, McClellan and Lee; at Gettysburg, Meade and Lee. Rosecranz and Weitzel were also officers of engineers. On the Southern side, among their greatest soldiers were Robert E. Lee, Joseph E. Johnston and Beauregard, all ex-officers of the Corps of Engineers. On both sides were many other engineer officers whose names I could give, such as Newton, Whiting, Ruger, Wilson, MacKenzie, Poe, Abbott, Putnam, O'Rourke, Merrill and others, who were distinguished as soldiers commanding troops. All this could not have come by accident.

ADDRESS OF J. G. SCHURMAN, LL.D., PRESIDENT OF CORNELL UNIVERSITY.

Mr. President, Ladies and Gentlemen,—Like the preceding speaker, I received a hint to be brief, and, like him, I shall endeavor to follow the suggestion. But in the few minutes which have been allotted to me I want, at any rate, Mr. President, to convey to you our sincere congratulations on finding you housed in so beautiful a building and in such an excellent location. It is becoming your profession to be progressive. Engineers are always moving forward. I never heard of stationary engineers (laughter); or, I never heard of but one, and that was during the Civil War, when Lincoln was anxious that McClellan should move on to Richmond, while the General kept hovering about the banks of the James. Some one called at the White House, and, knowing that McClellan was not in especially high favor just then, ventured, at any rate, to commend him as an engineer. "Yes," said Lincoln, after listening to him, "yes—but a stationary engineer" (laughter). This Society does not give any evidence of such an attribute. It is true to the requirements of the profession—it is advancing.

Your Society is very closely related, it seems to me, to what is most characteristic of our American civilization. If we go to the old world—if we go to Paris, or to Rome, or to London—we are shown there great collections of art, or memorable buildings, or venerable libraries, in which books and treasures may be found thousands of years old; but when strangers come to our country, we have nothing of that kind to show them. We deplore that art with us is almost in its infancy; that as yet we have produced no poem, no philosophy, no great work of art which will rank with first-class productions of the same kind in the old world. But we show them our bridges, our colossal buildings, our vast systems of railway, our electric lighting and other industrial organizations, and we feel that in these things are embodied the most distinguished achievements of the American spirit. And our greatest men, as General Craighill has indicated to you, have themselves been engineers. Washington, he says, was only a surveyor; but I suppose in those times he might have passed for an engineer, and I often wonder whether the experience which he gathered in West Virginia and on the banks of the Ohio may not have had something to do with

the wonderful skill with which he conducted his marches and countermarches and triumphant defeats.

Well, it is natural for us as Americans, you see, to congratulate the engineers. We know them, we appreciate their works, and we are aware that their achievements are not limited to our own continent. If we look to-day at the map of Africa, what changes have been wrought upon it within the memory of men now living, within the last ten or fifteen years, mainly by the engineer! Only this month they have opened a new line of railway which connects Buluwayo in the interior with the Cape of Good Hope; and at Buluwayo, within the last two decades, there lived a monster who ruled over the district, in which, as some of you know, all sorts of atrocities were practiced. What has wrought the change? Simply the triumphs of the engineer in bringing into the heart of Africa the civilizing influences which, through lack of communication and intercommunication, had hitherto been excluded. Or look at India. When the Declaration of Independence came out, the British held only a few acres of ground for a trading fort. What has happened since? Why, at the present time between three and four hundred million people there are subjects of Queen Victoria. That achievement is no doubt due to many causes. It is due to the political skill with which the English have used the natives to fight their battles; but it is due also to the invention of James Watt, who made it possible to connect the seacoast with the empire beyond the sea, and it is due also to the engineering skill by which roads and railroads have been run in and through every part of India. When Li Hung Chang visited us, some of you will remember that while he claimed for his own people that in philosophy and in works of reflection they equaled the profoundest philosophers that the world had yet produced, they were yet behind Europe and America, because they lacked what we have here and what you represent to-day—the science of engineering.

Nor are the achievements or your profession merely or perhaps primarily of a practical order. It is in the world of practice, of course, that we see the results. But, nevertheless, your profession ranks you with scholars, with the men who practice the learned vocations. It is only within the last generation that that has been recognized. But now in all our universities, the oldest as well as the newest, schools of engineering are established and the men who

graduate in them are placed on the same footing as the men who graduate in what used to be called the learned professional schools. If you take, for instance, the profession of law, there is not an institution in the United States which has so long a course for its graduates as many of them, and perhaps most of them, require from the civil engineer; and if only a few years ago men could walk from the streets, as it were, into the law schools, that has never been true of the schools of civil engineering, and the best of them to-day require of those who matriculate a knowledge of mathematics, which is equal to that formerly required in the old-fashioned colleges of the graduates in the B. A. course. We are coming to recognize throughout the country that engineering is a learned profession, and that the men who practice it need the same sort of scientific training and professional culture that is demanded of practitioners in law and in medicine. And the reason for this is perfectly clear. The engineer is applying the laws of Nature. Before you can have applied science you must have science to apply, and the works of the engineers rest on such fundamental sciences as mathematics, physics and chemistry, and no one can master these sciences in the thorough way which is now required for the solution of the great engineering problems of the age—no one, I say, can master them in a shorter time than that which is devoted to the study of law or to the study of medicine.

I am glad to think, Mr. President, that James Watt, whom I have already mentioned, although he lived over a hundred years ago, and before engineering schools had been established in any of our universities or in any universities in the world, was, nevertheless, associated with a university. On account of ill-health he was unable to complete his apprenticeship, and the guild to which he belonged refused to permit him to practice or to work in the City of Glasgow. But the college took care of him. They appointed him mathematical-instrument-maker, and it was while he held this subordinate position in the University of Glasgow that he began those studies on the Newcomen engine—which, as you know, was merely a steam pump—he began those studies, I say, which resulted in the production of the steam engine with a separate condenser. It is a satisfaction to me as a university man to recall that Watt, whom we may in some respects regard as the founder of engineering science, was in that way associated with the universities.

If I were asked what the desiderata of the engineering profession, as we see it at the present day, are, I should answer, first of all, you need, as all the learned professions need, to know more. Nature spreads out around us with infinite mystery. We have dipped in here and there and made shallow soundings; but the dimensions of attained knowledge, even if we take the knowledge of the race, are ludicrously small in comparison with the great ocean of mystery that stretches beyond. The ideal of the civil engineer—he may never attain it—but his ideal, if he is true to his profession, is so to master the laws of Nature that man may be able to control the powers of Nature and to make them serve his uses and minister to his needs. I often think that Shakespeare, universal genius as he was, defined, too, the ideal of your profession. In his ripest, and I suppose his latest play, "The Tempest," he has given us in Prospero the embodiment of the engineer, as also, Mr. President, the embodiment of the genius of true Christianity. Prospero is the man, you remember, who can forgive his enemies—forgive the brother who has ruined him and dethroned him, and pray for those who despitefully use him. But he is also the magician who can so wield all the powers of Nature that he has but to speak and the thing he wills is done. So long as there is crime or sin in the world there will be place for the preachers and the reformers and the prophets; and so long as you, gentlemen of this Association of Civil Engineers, fall short of that wonder-working ideal which is embodied in Prospero, will there be work and abundant work for you to do. May I venture to express the hope and the earnest wish that your housing in this commodious building may in some measure contribute to that high end (applause).

ADDRESS OF HON. JOSEPH H. CHOATE.

Mr. President and Ladies and Gentlemen,—Unfortunately for you I have received no intimation to be brief (laughter). But my safety lies, and yours too, in my little knowledge of the subject in hand (laughter). It was a great philosopher who said "One thing I know—that I know nothing," and always afterwards he was regarded as one of the greatest and wisest of mankind. But I do feel very grateful for the opportunity that has been given me on behalf, as it was suggested by the Committee, of the other professions, of welcoming this youngest, most vigorous, and, I believe, most useful, of all the learned professions in this very critical and important day in its life (applause). There is necessarily a fellowship and a very close fellowship among all the learned professions. We are all engaged alike in studying and applying laws to the uses and convenience of mankind, and in that respect the engineers, as it seems to me, have a very decided advantage over the other and older professions. They work from known and certain premises to inevitable conclusions. Theirs is an exact science, based not upon opinion, based not upon judgment, but upon absolute and fundamental facts in respect to which they ought not and cannot be allowed to err. But we of the other professions stand very differently. Ours are all uncertain—based upon opinion, upon experiment, upon judgment. When the doctor loses his patient, it is never his fault (laughter). He goes on, he lives on, and acquires new patients and new fame (laughter). When the lawyer loses his case, it is never his fault (laughter). He can always trace it to the infirmities of the law, or the weakness of the judge, or the dullness of the jury, or the evil conduct of his client (laughter). But it is not so with the engineer—the civil engineer; with him a blunder is indeed a crime. If his bridge falls, he falls with it. If his tunnel collapses, he collapses with it—and had better be buried in its ruins. Now, there is another respect in which, as I think, the profession of engineering has another very decided advantage over us. Our works perish. The breath of the lawyer is the measure of his fame. The rules, the practice and the law of the medical profession change from age to age, and—if the Bishop will allow me to say so—even the dogmas of theology are not forever unchangeable (laughter and ap-

plause). But the works of the engineer live after him as an enduring monument to carry down to a distant posterity his merits and his defects.

In a little term of leisure last winter I wandered over the Island of Sicily, and on the heights of Urias overlooking what once had been the site of the City of Syracuse, which had absolutely disappeared so that not a vestige of it remained. The great fortifications that the predecessors of Archimedes had built under that lofty hill remained unchanged as they were built for military purposes more than two thousand years ago. At Girgenti and Pæstium we gazed upon temples still standing, in form perfect, as they were erected by engineers and builders whose names have been forgotten, still holding out models of beauty and grace for the imitation and instruction of mankind. At Rome we rode over the bridge of St. Angelo, more than a thousand years old. We stood under the dome of that matchless model of architecture, the Pantheon, as perfect apparently as when the name of its builder, Agrippa, was emblazoned upon its front. We stood before the ruins, the matchless ruins, the splendid ruins, of the Coliseum. All these great structures testifying to a far-distant posterity of the power and the beauty that dwelt in the minds of their designers; and I have been wondering since I was invited to take part in these proceedings whether any works yet constructed by engineers or builders in this America of ours shall last as long as those; whether the men of the thirtieth century, the students of architecture, of engineering, will find something yet to admire, even though it be in ruins, of the works of the men of the nineteenth and the twentieth centuries? That question I shall prefer to leave to these distinguished experts who are members of this American Society of Civil Engineers. But the truth nevertheless does remain that the work of these great engineers of to-day, the men who build our great bridges, our great docks, our great tunnels, our great railroads, will be carried down to a posterity that will long since have forgotten the doctor, the lawyer, and even the clergyman, who are now ruling over us.

I think it a very fortunate thing in respect to these days and events that the opening of this building for the use of the American Society of Civil Engineers is exactly coincident with the starting of this great metropolis in which we live and of which, in spite of its mistakes, we are all so proud, upon its new and greater career (applause). Why,

New York is only an infant to-day. She is just bursting her swaddling bands. She has outgrown herself and is really bursting her bands in all directions. You cannot venture into the streets without the peril of losing your life as a sacrifice to the great engineering works that are going on to-day (applause and laughter). And I am sure that that great province for engineering now extending over an area of 350 square miles—359 square miles is the exact quantity—holds out more work for the conscientious, the intelligent and the skillful engineer than all America did fifty years ago (applause). What bridges are to be built over these noble rivers! What tunnels are to be excavated! What roads laid out! What docks constructed! Why, think of it; we have one project now pending before us, one work of tunneling and of bridging and of road building at an expenditure—the appalling expenditure—of 50 millions of dollars! Now, what I hope is that the new administration which the people of this city in their wisdom have elected to preside will come here—I hope they are here (laughter)—I hope the Mayor-elect is here, to learn a lesson that no other place could teach as well as this; that the great engineering works of this city, which are to absorb millions upon millions of the people's money and occupy years and decades in their construction, shall be placed under the charge of competent engineers as the heads of the departments in which the public works belong (great applause). I think the science of engineering has advanced so far, and I hope the science of municipal government has advanced so far, that hereafter it will not be considered sufficient to have as Commissioner of Public Works either a lawyer or a politician who is as ignorant of engineering as the unfortunate person who now has the honor of addressing you (laughter).

This Society well calls itself the American Society of Civil Engineers because it is a truly national institution for the service of the whole nation, made up of educated engineers, engineers in every branch of civil engineering. Now, President Schurman has said something about its being a new profession, and General Craighill asserted that it was the oldest profession that he knew anything about. Well, that is only a difference of verbiage, of phraseology. It is true that fifty years ago there were not many civil engineers, and if they had been presented to an audience like this, the audience would have been quite at a loss to know what they were (laughter). But they have been train-

ing, and are being trained from the beginning. It is true the colleges did not do much for them. I remember when ex-President Morison, one of the most distinguished engineers of this country, and one of the most distinguished ex-Presidents of this Society, left Harvard College, he found it necessary to spend a year or two in my law office to lay the foundations of that great engineering fame (laughter and applause). And I am happy to say now that three successive Presidents of this Society, including the gentleman who presides here to-day, are graduates of Harvard College. I think it shows what we believe in the other professions, that for technical education there must first be laid as a foundation a broad, liberal education (applause). But I was going to say what the engineers had done for the Nation. It is true they have not been the founders of the Nation; but they have been the makers and the builders of the Nation. Now, let us see exactly how that is in a very few words. When this Nation was founded, for I look upon the making and adoption of the Federal Constitution in 1787 as the founding of the Nation, there had been no engineering and no engineers in America except the military gentlemen whom Washington had summoned to his aid for the conduct of the war. There was no bridge over any navigable river in what now constitutes the United States; no harbor but presented its natural appearance as it had been from the beginning of time. Of course, no railroads, no tunnels, no roads worthy of the name, of any description. Why, then, it took the Members of Congress who went in their own carriages from Boston to Philadelphia six days to make the journey, and they had to cross in ferries the mouths of six navigable rivers. Two hundred years had been spent by the settlers in grappling with the wilderness, and in desperate struggling. What had been accomplished? Fifty miles in breadth along the Atlantic coast, from Maine to Georgia, was all that then represented the triumphs of those two centuries. Well, then, the Federal Constitution was adopted. You remember that memorable scene on the day when Hamilton wrote the names of the States on the last page of the document, at the foot of the document, and Washington and Franklin and all the rest of them subscribed their names. Franklin, looking at the painted sun that was behind the chair of Washington, who presided in the convention, said: "All through these debates I have been wondering whether that was a rising or a setting sun. Now that these names have been signed to that immortal

document, I am sure that it is a rising sun." But if Washington and Franklin, the two wisest members of all that wise gathering, could have foreseen that within a hundred years the area of the United States—in which the constitution which they then formed was to carry the blessings of liberty to a distant posterity—was to extend not simply from the Atlantic to the Mississippi, but three times as far—from the Atlantic to the Pacific, and from the Gulf to the Lakes, and that in the ordinary administration of executive power it might be necessary for the President to issue an order, for the very salvation of the Republic, that should be obeyed within one hour on the Pacific coast—if they had contemplated that it might be necessary to transport in three days three hundred thousand men from the Lakes to the relief of the beleaguered capital—even they would have trembled at the sublime audacity of the experiment that they were undertaking (applause). Why Franklin himself, with all his power, with all his learning—he had snatched the lightning from the clouds and the sceptre from tyrants ; he knew all about steam that anybody knew ; he was the matchless master of electricity up to that date, and yet even he had no conception of the means and appliances by which this nation was after all to be made one. Let me read you what he said only the year after the convention adopted the Constitution and adjourned. In writing to a friend of his in the month of October, 1788, from Philadelphia, he says :

"We have no philosophical news here at present, except that a large boat rotated by the force of steam is now exercised upon our river, stems the current and seems to promise being useful when the machinery can be more simplified and the expense reduced" (laughter).

And Mr. Madison in the *Federalist*, in arguing very laboriously the possibility of the Federal Government exercising efficient control over our vast territory as it then extended from the Atlantic to the Mississippi and from Maine to Georgia, says:

"The difficulties will indeed be great, but as the nation will extend no further than the Mississippi and no further south than Georgia, it will be quite practicable for the delegation from those distant regions to reach the seat of government in time to take part in the deliberations of Congress" (laughter).

And now what do you see ? What has been done since then ; all done by these engineers ? As Mr. Seward said at the outbreak of the

War of the Rebellion: "No parchments, no laws, will hold this nation together; but bridges and railroads and steam and the telegraph, they will and must do it" (applause).

Now, I will not detain you, for you all know what these engineers have done. The highway from the Atlantic to the Pacific was the very saving of our Pacific seaboard, the Rocky Mountain States, to the Union. You all know perfectly well what immense works, both public and private, have been constructed by them in every quarter of the Union; how peace and plenty, and order and law, and art and civilization have followed in their track; how they have made commerce so fruitful, the people so flourishing and happy and have brought with them to stay prosperity throughout the land (applause).

Now, when I received this invitation I thought I would like to know something about some engineers, and I got one of the most entertaining books or set of books that I for one have ever read. As there are some here who are not engineers, I advise them to get it and read it, and that is Smiles' "Lives of the British Engineers." They are more fascinating, each one of them, than anything that can be found in the Arabian Nights—more bewitching in their fortune, their character and their achievements. They all seem to tell one story. They had no colleges, they had no universities where they could study the elements of their profession. They were almost uniformly sons of laborers, born in laborers' cottages, nurtured under hardships, apprenticed to a youth of hard labor, manifesting always indomitable courage, vast power of labor, a perfect passion for construction, and patience that knew no end, and courage that equaled anything that any warrior ever exhibited, and conscience always—it is one of the most honest and conscientious professions that has yet come into the world (applause). They stumbled upon their first works apparently almost by accident. They showed themselves worthy by the perfection of the work they did, the conscientiousness with which they did it, and they went on from one piece of work to another, ever greater and grander and grander; and when they were called to their last home they were followed to the grave, not by humble cottagers who had surrounded them at birth, but by kings and nobles and the intelligence, the brains, the culture and the wisdom of the realm. Where did they end their careers? Just where they should, among the greatest benefactors of mankind, in Westminster Abbey. Doubtless all of you remember that splendid

statue of Watt, to whom President Schurman has already referred, by Chantry, on which is inscribed an epitaph prepared by Lord Brougham which he counted the greatest honor of his life to have been permitted to write; and then, too, you find as you walk through the nave the graves of Thomas Telford and of Robert Stephenson—two more of the great benefactors of the human race—the one the "Colossus of Roads," as his friend Southey delighted to call him; the other the perfecter of the locomotive. He and his greater father—if I may be permitted to call him so—George Stephenson, had worked together in the development of that vast machine upon which now the prosperity of the human race itself depends.

Now, how did they do all this? How did these great engineers achieve these marvelous triumphs? Well, I think it was only—to borrow a phrase of Emerson's—by hitching their wagon to a star, and if you will permit me to read a few words from Emerson in conclusion, which I think he intended for just such an occasion as this, and in writing which I believe he had in mind the American Society of Civil Engineers and all civil engineers in general, you will understand what I mean when I say that, recalling Lord Bacon's phrase, that every man owes a debt to his profession, that the debt that these civil engineers owe is to follow in the footsteps of those great men whom they all unite in honoring and revering; and now, if you will allow me to read this short passage from Mr. Emerson, I will take my seat. He says:

"Now, that is the wisdom of a man, in every instance of his labor, to hitch his wagon to a star and see his chore done by the gods themselves. That is the way we are strong, by borrowing the might of the elements. The forces of steam, gravity, galvanism, light, magnets, wind, fire, serve us day by day and cost us nothing. Hitch your wagon to a star. Let us not fag in paltry works which serve our pot and bag alone. Let us not lie and steal. No god will help. We shall find all their teams going the other way—Charles' Wain, Great Bear, Orion, Leo, Hercules: every god will leave us. Work rather for those interests which the divinities honor and promote—justice, love, freedom, knowledge, utility. If we can thus ride in Olympian chariots by putting our works in the path of the celestial circuits, we can harness also evil agents, the powers of darkness, and force them to serve, against their will, the ends of wisdom and of virtue" (prolonged applause).

RESOLUTIONS ADOPTED.

During the meeting the President read the following dispatch from the Institution of Civil Engineers :

"Congratulations to the American Society on opening their New House."

George S. Morison, Past President Am. Soc. C. E,, then spoke as follows :

Mr. President, I believe that all the members of the Society who are present are very glad to hear our profession spoken of in the way in which it has been mentioned. It is right, however, for us to recognize that though we consider ourselves a great profession, our greatness must be in the future rather than in the past, and that we are just being welcomed into the ranks as the youngest brother among the older professions. I think, therefore, that it is right that we should do something in appreciation of what has been done for us to-day, and I would therefore offer the following brief resolutions :

"*Resolved*, That this Society tenders its thanks to the representatives of the university, of the law and of the clergy who have so kindly joined us in the dedication of our new home.

"*Resolved*, That this Society has received with great satisfaction the congratulations of the oldest and greatest engineering institution that the world has ever known, and hopes that the warm fraternal relations of older and younger brethren may always continue between the two organizations."

I offer these resolutions.

The resolutions were adopted.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

EXPERIENCE WITH A NEW MACHINE FOR TESTING MATERIALS BY IMPACT.

By S. BENT RUSSELL, M. Am. Soc. C. E.

When stress is applied to a solid body, the material is distorted and a certain amount of work or energy is absorbed. The work thus absorbed in the deformation of the material is called resilience. If the stress changes from zero up to the elastic limit of the material, the energy absorbed during the change is the "elastic resilience" of the material. If the stress changes from zero up to the ultimate strength of the body, the energy absorbed is the "ultimate resilience" of the body.*

In the study of this subject it must be borne in mind that resilience is work, and hence depends upon two essential factors, force and distance acted through. The latter is fully as important as the former. The word toughness, as used by engineers, is synonymous with resilience. In fact, the latter may be defined by saying that resilience is toughness reduced to measurement.

Having defined resilience, it is next found that, as it depends upon change of stress, different results may be looked for when the stress is

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. The papers with discussion in full will be published in the volumes of *Transactions*.

* This use of the word resilience will be objected to by some as not being in conformity with the original meaning of the word. It is sanctioned, however, by some authorities (see Thurston's "Materials of Engineering"), and, for want of a good substitute, may be considered as a technical term.

applied suddenly, from those obtained when it is applied slowly. The resilience under impact may not be the same as the resilience under gradual load. In this connection impact should not be confused with sudden load. The effect on resilience of rapidity of change in stress can only be determined by actual experiment. This is especially true in the case of material not perfectly elastic, or where the stress has passed the elastic limit of the material.

Again, the resilience of solids may be studied under the four principal kinds of stress, viz., tension, compression, torsion and bending. The relative resilience under these different forms of stress can only be determined by experiment. A knowledge of the resilience of materials of construction is of the greatest importance to the engineer. It is the great resilience of the battle ship's steel armor that enables it to withstand the impact of heavy projectiles without destruction. It is the low resilience of cast iron that makes it so inferior for railway bridges. It is on account of the high resilience of wood that it cannot, in many cases, be supplanted by masonry, glass or other decay-proof material. A concrete railroad tie cannot take the place of the oak tie because it lacks resilience.

Admitting the importance of a knowledge of resilience, a brief consideration of the difficulties to be overcome in obtaining such knowledge is naturally to be considered next. It is at once found that they are of considerable proportions. To find the strength of a beam under given conditions it is only necessary to find its weakest section and study that. To find the resilience of the beam all sections must be taken into account. If the beam is irregular in form, the problem becomes quite a difficult one. If the final stress exceeds the elastic strength of the material, the difficulties are increased.

The actual measurement of the resilience of a beam has been found quite difficult. The load must be increased gradually and the deflection measured and recorded with its corresponding load. As the breaking point is neared the difficulties of accurate work become important, especially in the more ductile materials. If the determination of the resilience by impact or drop test is attempted, other complications arise. The mass or weight of the beam itself now becomes a factor in the test. The work absorbed by the anvil and hammer and that taken up in abrasion, etc., are difficult to estimate.

To one who has a proper understanding of these difficulties in

measuring resilience, it is not surprising that the subject is somewhat neglected in the studies of practical men. At present it may be said that the knowledge of comparative resilience of materials is "appreciable, but not describable." It is known that a cubic inch of oak has more resilience than a cubic inch of white pine, but the value of either cannot be expressed in inch-pounds or foot-pounds. What is known about resilience, and the modern methods of determining its value, will be briefly considered.

An interesting series of experiments on the resilience of beams under impact was made by Mr. Hodgkinson. The following quotations from a book well known to engineers* will show the more important results of these experiments:

"The power of a beam to resist impact is the same at whatever part of the length it is struck; * * * this remarkable result has been confirmed by experiment."

"In rectangular beams of unequal dimensions the resistance† is the same, whether the bar is struck on the narrow or broad dimension."

"With rectangular beams the resistance to impact R is simply proportional to the weight of the beam between supports, irrespective of the particular dimensions."

The above laws exclude the effect of inertia.

"Mr. Hodgkinson has shown by his experiments that in resisting impact, the power of a heavy beam is to that of a light one as the inertia of the beam, plus the falling weight, is to the falling weight alone, or as $\frac{I + W}{W}$."

"I is the inertia of the beam and the load upon it."

"The inertia of a beam, uniform in cross-section from end to end, supported at the ends and struck in the center, may be taken at half the weight between supports. * * * To this has to be added the whole central load, if any."

In the second column of Table No. 20 will be found some values for the resilience of certain materials, which were obtained from the book above referred to.‡ In modern practice, the testing of materials by impact is by no means uncommon. Such tests, however, are generally made on the finished shape, as in the case of railway axles. In a code for testing materials, recommended by committee to the

* "Strength of Materials" by Thos. Box.

† Resilience?

‡ Interesting matter on the subject of impact, resilience, etc., will be found in *Engineering News*, August 2d, 1894.

American Society of Mechanical Engineers,* it was prescribed that drop tests should be made with a steel ball, weighing 1 000 to 2 000 lbs., having a clear fall of 20 ft. The anvil, block, frame, etc., should weigh not less than ten times as much as the ball. Drop tests were recommended for rails, tires and axles. Again, the Master Car Builders' Committee,† have recommended drop tests for railway axles. These tests were to be made with a trip, weighing 1 640 lbs. The anvil should weigh 17 500 lbs., and should rest on springs. The axle should rest on supports 3 ft. apart. Cast steel drawbars are now regularly furnished by contract, under specifications which call for drop tests of sample drawbars, specifying weight of trip, height of drop and number of blows. Drop tests of steel rails have been in practical use for many years.

Besides the above tests of finished shapes, the following methods, which are used in commercial practice, may be noted. These tests, while they do not measure the resilience so directly, are, nevertheless, intended to prove the toughness of the material.

In testing cast-iron water pipe by hydraulic pressure, it is customary to strike the pipe smartly with a hand hammer while the pressure is on. In inspecting steel where a sample bar is nicked and then bent with the hammer, the behavior of the bar indicates the degree of toughness which the material will have under impact. A high percentage of phosphorus in steel is believed to reduce its ability to withstand shocks, while its strength and percentage of elongation remain unchanged.‡ So that it may be said that the specified chemical determinations of phosphorus in structural steel which are now in use are really indirect tests of resilience under impact.

Users of structural steel will readily see the necessity which now exists for a definite physical test for the ultimate resilience of steel under impact. It was this special necessity which led the author into the study of the subject and suggested the experiments described in this paper.

If, instead of limiting the percentage of phosphorus in the steel, a certain ultimate resilience per cubic inch of the metal when tested by impact could be called for, a step would be made in advance. If a

* See *Engineering News*, March 7th, 1891.

† See *Railroad Gazette*, June 26th, 1896.

‡ See Johnson's "Materials of Construction," pages 166 and 167.

definite resilience under impact could be specified, just as a definite strength and ductility are now called for, the proper inspection of steel would be much more simple and satisfactory.

The difficulties of making impact tests have already been suggested. Some machines which have been used for making such tests are of a type greatly open to criticism. For example: In some machines the supporting parts are either so light or so yielding that an important part of the energy of the blow is absorbed by them, and the test piece appears to sustain a much heavier blow than it would in fact on the proper rigid supports.

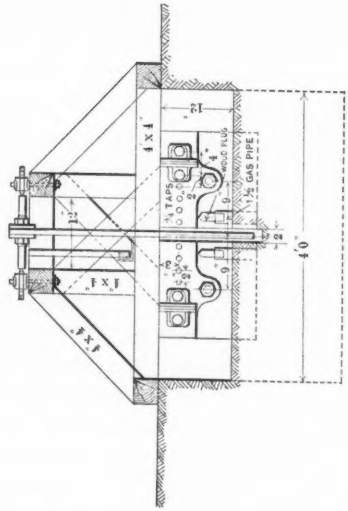
Two general forms of testing machine have been used in recorded tests. In Mr. Hodgkinson's experiments the hammer used was in the form of a pendulum striking with a horizontal blow. The weight of the hammer was concentrated in the head or ball, and the effect of the rod or radius arm was probably neglected. The most common form of impact testing machine is doubtless the heavy weight falling vertically, somewhat after the fashion of the common pile-driver. In none of these machines is there any means for measuring how much energy is left in the hammer after breaking the piece.

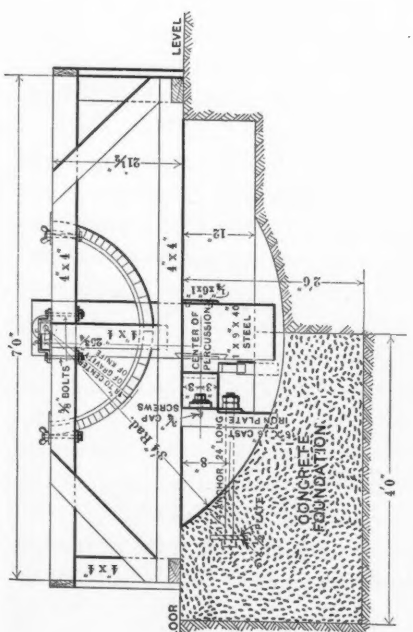
The Impact Testing Machine.

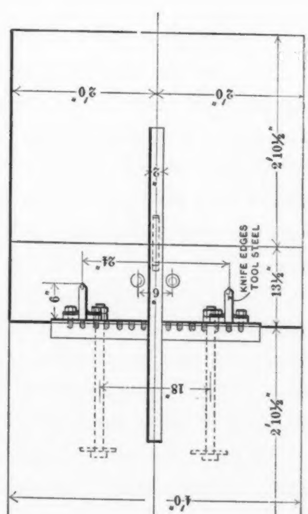
The machine used in making the experiments given herewith was devised by the author and has some special features.

In designing it the main idea was to make a machine which would measure the energy actually absorbed in breaking the test bar. This was to be done by using a hammer in the form of a pendulum, and so arranged that it would strike a horizontal blow, breaking clear through the bar and swinging freely up to the height due to the velocity after the impact. The difference between the height through which the hammer fell before striking, and the height to which it rose after striking, would measure the energy absorbed in breaking the bar. The test piece would rest against two vertical knife-edges and be struck in the middle by the falling pendulum, thus giving the ultimate resilience of the bar under transverse stress.

In developing this idea it was found best to make the pendulum or hammer of the very simplest form, so that the center of percussion and center of gravity could be definitely computed. The hammer







FIGURES 1, 2 and 3.

adopted was a rectangular steel bar pierced by a shaft at the upper end and provided with a suitable striking edge near the lower end.

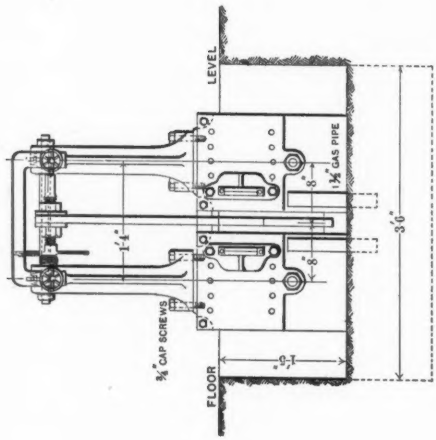
Figs. 1, 2 and 3 show the form and dimensions of the machine used in the experiments. Plates XXVI is from a photograph which shows somewhat imperfectly the general appearance of the apparatus. The hammer used weighed 103 lbs. The fixed knife-edges were designed so as to allow the broken bar to swing out of the way of the moving hammer, and were secured in a manner which allowed them to be adjusted for spans of 8, 12, 16, 20 and 24 ins. The heavy anvil plates behind them were bolted to a large anvil block of concrete which was sunk in the earth. Adjustable supports were provided to hold the test bar in position. The pivot blocks which support the hammer shaft are adjustable to allow for test bars of different depths. Attached to the hammer shaft is a registering device on which the swing of the hammer is read. The pivot blocks, etc., are supported by a strong wooden frame. Attachments are provided for raising and releasing the hammer. The plans for this machine were made in May, 1896. In making the design, the author was assisted by Mr. William F. Schaefer and Mr. Vernon Baker.

Figs. 4, 5 and 6 show the plans and Fig. 12 the details of a later design which it is thought embodies some improvements in detail, although the essential features are the same. In this design the frame will be of iron and the operator will have more room in which to work while setting the test bars in place.

In using the testing machine the first point that comes up is the loss due to friction of the hammer in its bearings. In practice it was found best to determine the friction anew for each set of experiments. If the bar was to be given a blow of 6 ins., the friction loss was determined for a fall of 6 ins. If the hammer rose 2 ins. after breaking the bar, the friction loss for a fall of 2 ins. was determined by trial. The average of the two values was called the correction for friction.

To test the rigidity of the knife-edges and their supports, a nickel 5-cent piece was placed on edge on the top end of one of the knife-edges. A cast-iron test bar 2 ins. by 1 in. was then broken by a single blow. This experiment was repeated a number of times, and, in the majority of cases, the coin was not overturned by the shock.

An effort was then made to measure the movement of the knife-edge under a heavy blow. The movement was found to be so small that in



Figures 4, 5 and 6.

the case of a cast-iron test bar, the energy absorbed by the yielding of the knife-edges would be quite inconsiderable. Every impact testing machine should be tested in this way, to see if any considerable percentage of the energy is absorbed by the yielding of parts that support the test piece.

In this method of testing materials some energy is absorbed in overcoming the inertia of the bar itself. The proportionate amount of this energy is probably dependent on the weight of the test bar compared with the weight of the hammer, and also upon the velocity of the hammer.

Owing to the difficulties of ascertaining how much energy is absorbed in this way, it is best to use a test-bar whose weight is small in comparison to that of the hammer. In this way the error due to inertia of the test piece can be reduced, if not eliminated.

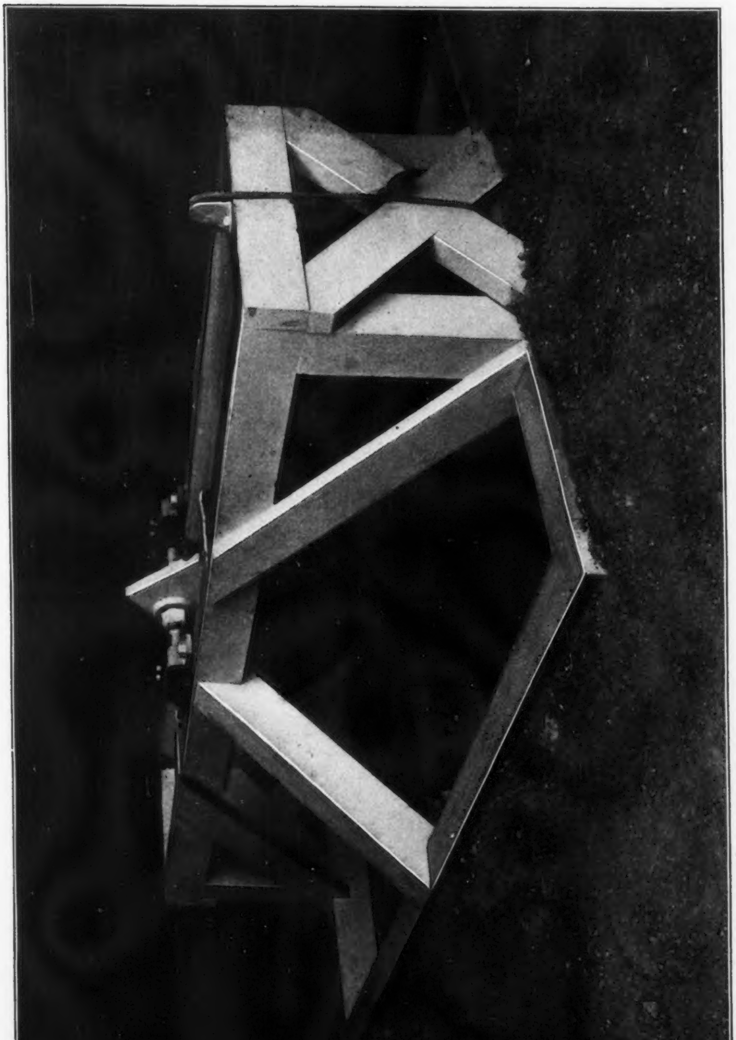
In Table No. 5 will be found the results of tests made to determine the effect of changing the initial fall of the hammer. The results are somewhat contradictory, but, in a general way, it may be said that the experiments indicate that a small change in the initial fall of the hammer will not change the amount of energy absorbed, to any great degree. This conclusion may be regarded as important, as upon it depends somewhat the interpretation of all the experiments. Table No. 5 will be referred to again in its proper order.

The machine having been described, it only remains to present the experiments themselves. Over 700 specimens have been broken, up to the present writing. These tests are not all recorded here; only those which were thought to be most instructive are given. In order to learn the possibilities of the testing machine, the study of each material was continued only until it was thought that the principal difficulties peculiar to such materials had been overcome. It is obvious that the resilience values obtained for different materials cannot be taken as final, and should only be used by the designer in the absence of more accurate determinations. All the experiments were made by the author, with the assistance of Mr. William F. Schaefer.

Tests of Brittle Materials.

The first tests were made with cast iron. Table No. 1 shows the resilience of cast-iron bars tested both by impact and by gradual load.

PLATE XXVI.
PAPERS AM. SOC. C. E.
DECEMBER, 1897.
RUSSELL ON IMPACT TESTING EXPERIMENTS.



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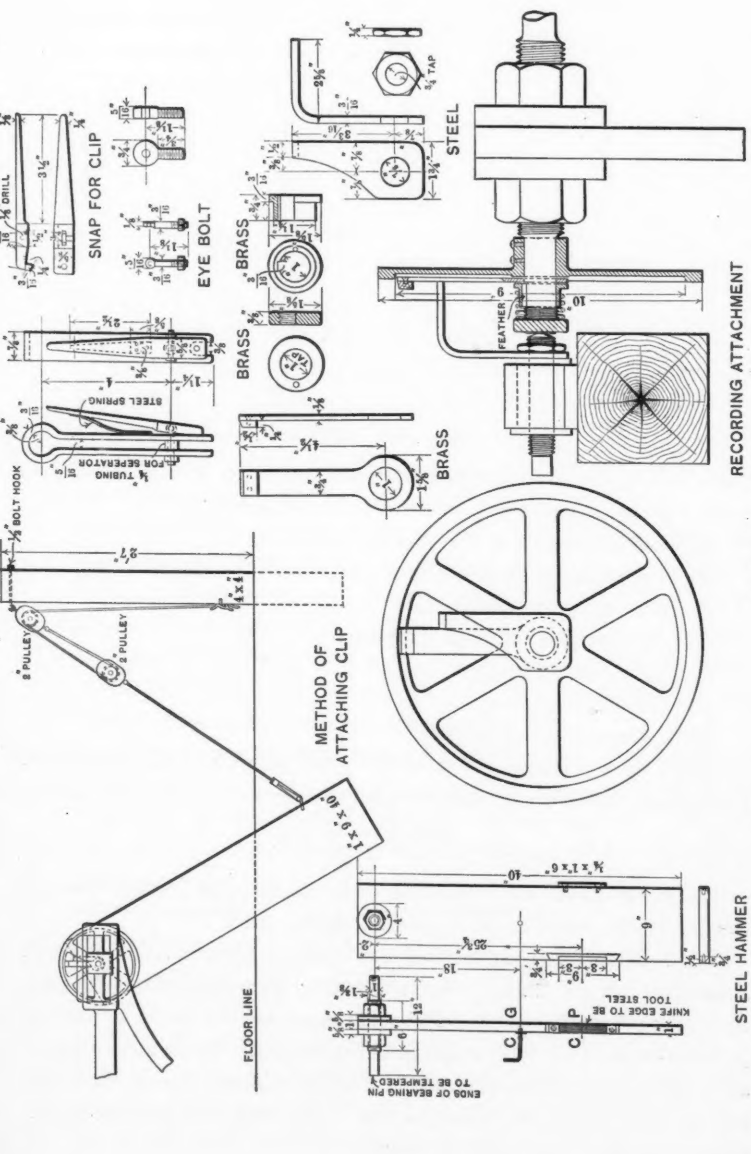
SNAP FOR CLIP
EYE BOLT
BRASS
BRASS
BRASS
BRASS
STEEL
STEEL SPRING
¼" TUBING FOR SEPERATOR
½" BOLT HOOK
2" PULLEY
2" PULLEY
METHOD OF ATTACHING CLIP
RECORDING ATTACHMENT
FEATHER
¾" TAP
FLOOR LINE
STEEL HAMMER
KNIFE EDGE TO BE TOOL STEEL
ENDS OF BEARING PIN TO BE TEMPERED
¼" x 1" x 6"
1" x 6" x 40"
4" x 4"

FIGURE 12.

TABLE No. 1.—Resilience by Impact and by Gradual Load.

Cast-iron bars 1 in. by 2 ins., broken flatwise.

Lot or Melt Nos.	Experiment Nos.	By Impact.			By Gradual Load.	
		Number of tests.	Length between supports in inches. L.	Resilience per cubic inch in inch-pounds. R_1.	Number of tests.	Resilience per cubic inch in inch-pounds. R_0.
1...........	125-130	6	24	11.5	3	9.0
2...........	137-139	3	24	10.8	3	8.7
3...........	156-159	4	24	11.4	3	8.5
4...........	219-222	4	24	11.8	3	8.8
6...........	391-393	3	12	17.9	2*	11.1
7...........	448-449	2	12	14.8	2*	8.2
Averages..	....	....	....	13.03	....	9.05

* $L = 24$ ins. with gradual load.

Each value given is the average of several tests. In making the impact tests, the following values are obtained by observation:

$F =$ the initial fall of the hammer in inches.

$S =$ the rise after the blow in inches.

$C_1 =$ the correction for friction.

$L =$ the distance between supports.

$h =$ the depth of beam.

$b =$ the width of beam.

All dimensions are in inches.

Then, by computation, when 103 is the weight of the hammer in pounds, the resilience in inch-pounds per cubic inch of the material; or

$$R_1 = \frac{103\,[F - (S + C_1)]}{L\,h\,b}$$

Table No. 19 shows a series of observations just as they were recorded by the observer, and extended in the office.

The resilience by gradual load was obtained by breaking the bar in a standard testing machine and accurately measuring the deflections up to the point of rupture. The resilience was then taken as half the product of the load by the maximum deflection. The true resilience, as obtained by a strain diagram, would be slightly greater than this, but the error is not important as the strain diagram for cast-iron is nearly straight to the point of rupture.

TABLE No. 2.—RESILIENCE FOR DIFFERENT SPANS.

Cast-iron bars, 1 in. by 2 ins., broken flatwise.

Lot No.	Experiment Nos.	24-IN. SPAN.		12 IN. SPAN.		
		Number of tests.	Resilience per cubic inch in inch-pounds. R_1.	Experiment Nos.	Number of tests.	Resilience per cubic inch in inch-pounds. R_1.
1...........	125-130	6	11.5	131-136	6	11.7
2...........	137-140	3	11.0	146-155	10	11.0
3...........	156-159	4	11.4	170-174	5	12.7
5...........	296-299	4	9.9	300-303	4	10.2

Returning to Table No. 1 and comparing the resilience by impact and by gradual load, it will be seen that the former exceeds the latter more than 40 per cent. This difference is so great that it can hardly be accounted for by losses due to inertia of bar, indentation, or movement in supports. The bar is light compared with the hammer, so that not more than 7% could be lost by inertia according to Mr. Hodgkinson's rule. The supports are so rigid that not more than 1% could be lost by their movement. The indentation is so slight as to be inconsiderable when compared with the deflection of the bar, hence there can be no great loss in this way. The logical conclusion is that more energy is absorbed in the sudden rupture of a bar than is the case with rupture under a gradual increase of load.

It has occurred to the author, that perhaps the causes of this difference may be traced back to the heat which is liberated under change of stress. Under gradual increase of stress the heat liberated has time to be conducted away from the distorted fibers. In the case of sudden rupture, the heat has no time to escape and must produce a rise in temperature. If this be admitted, it seems not impossible that the resilience may be affected by the rise in temperature of the distorted particles. This suggestion should be taken for what it may prove to be worth.

Table No. 2 needs no explanation. Bars of the same melt, but of different spans, are compared. A bar of 12-in. span has twice the strength and one-quarter the deflection of a bar 24 ins. in span. With the former, then, a greater loss of energy by movement of the knife-

edges and by indentation might be expected. Theoretically, the error from these sources would be about eight times as great for the shorter span. On the other hand, the error from inertia should be about twice as great in the longer span as in the shorter one. It will be seen by the table that the difference in the resilience per cubic inch ranges in value from nothing up to about 10%, and that the shorter span shows the higher average resilience. It is fair to conclude from these experiments, as far as they go, that the ultimate resilience of a bar of cast-iron is proportional to its volume and is independent of the span.

TABLE No. 3.—Resilience of Cast-Iron Bars.

Cross-section, 1 in. by 2 ins. Span, 24 ins. Melt No. 2.

Position.	Experiment Nos.	Number of tests.	Resilience per cubic inch in inch-pounds. R_1.
Flatwise	137-139	3	10.8
Edgewise	140-143	4	9.1
Average	....	....	9.95

Table No. 3 shows that a flat bar has about the same resilience whether broken flatwise or edgewise. All these bars were cast from the same melt. In the case of a bar 2 ins. wide and 1 in. thick, it should have, when broken edgewise, twice the strength and half the maximum deflection that it would have flatwise. The error from yielding supports and from indentation should be about four times as great in the former position. The error from inertia of bar should be the same in both cases. It would be expected that the bars would show greater resilience when broken edgewise. The absorbed resilience was, however, somewhat greater in the average, with the bars broken flatwise. This may be regarded as evidence that the errors due to yielding supports and indentation are not great.

As in testing bars in this manner, it is possible for the experimenter to raise the hammer considerably higher than is necessary to break the bar, the question naturally comes up: Will the height to which the hammer is raised affect the results obtained? A number of experiments were made to decide this point, and the results are recorded in Table No. 5. The experiments were made in this manner: Twelve to sixteen bars were taken from the same melt of cast-iron.

TABLE No. 4.—RESILIENCE OF CAST-IRON BARS.

Effect of planing. Melt No. 4.

	Experiment Nos.	Number of tests.	Span in inches. L.	Depth of beam in inches. h.	Width of beam in inches. b.	Weight of bar in pounds. W.	Resilience per cubic inch in inch-pounds. R_1.
Rough..........	215-226	12	24	1	2	13	11.6
Planed..........	253-263	11	12	0.91	1.93	5.7	21.1

NOTE.—For effect of span, see Table No. 2. All bars were rectangular.

Four of these bars would be broken with the hammer falling 5 ins., which would barely break them. The resilience would be measured. The next four bars would be tested with the hammer falling 6 ins.; the next with a fall of 7 ins., etc. The results obtained will be seen in the last column of the table. It is evident that more experiments would have to be made to find the true relation between the height through which the hammer falls and the energy absorbed in the rupture. It is fair, however, to conclude in a general way, as has been stated, that a slight increase in the height will not materially affect the results obtained. There seems to be a tendency for the resilience to increase as the height is increased; but this tendency is all but concealed by variations from other causes.

Coming back to the regular order: Table No. 4 shows the effect of planing on the resilience of a cast-iron bar. The results shown are somewhat remarkable. The bar, after planing off the surface on all four sides, is much tougher than it was before. This difference cannot be due to any fault in the method of testing, as may be seen from a comparison of this table with Tables Nos. 2 and 3. The superiority of the planed bar is probably due to the lessening of the shrinkage strains when the surface of the rough casting is removed. It is possible that the same gain might be made by annealing the rough bar. The discovery of the great increase in resilience after planing might have been prophesied, perhaps, from studies heretofore made of the loss of strength due to shrinkage strains. This fact, however, has never before been demonstrated by actual impact tests, to the

TABLE No. 5.—RESILIENCE OF CAST-IRON BARS.
Effect of increasing initial fall of hammer.

Melt.	Experiment Nos.	Number of tests made.	Size of Bar. Span. L.	Depth. h.	Width. b.	Weight of bar in pounds. W.	Initial fall of hammer in inches. F.	Resilience per cubic inch, in inch-pounds. R_1.
3........	156-159	4	24	1	2	13	7.0	11.4
	164-167	4	24	1	2	13	9.5	12.1
	160-163	4	24	1	2	13	12.0	12.5
3........	170-174	5	12	1	2	6.5	4.0	12.7
	180-183	4	12	1	2	6.5	6.5	13.0
	177-179	3	12	1	2	6.5	9.0	16.8
	175-176	2	12	1	2	6.5	12.0	15.2
4........	219-222	4	24	1	2	13	6.0	11.8
	223-226	4	24	1	2	13	7.5	11.6
	215-218	4	24	1	2	13	9.0	11.5
4*.......	253-255	4	12	0.9	1.9	5.7	5.0	21.2
	249-252	4	12	0.9	1.9	5.7	6.0	19.1
	256-259	4	12	0.9	1.9	5.7	7.0	21.9
	260-263	4	12	0.9	1.9	5.7	8.0	22.3

* Planed.

NOTE.—All bars were rectangular.

author's knowledge. The great advantage of finishing castings exposed to shocks should be taken into account by designers of machinery.

Table No. 6 gives the results of tests of paving brick. The first tests of brick made with the hammer were unsuccessful on account of the great thickness of a brick compared with its length. The broken brick would wedge between the hammer and the opposing knife-edge, so that the hammer could not swing through. To remedy this, the author devised a knife-edge which would be immovable when struck squarely, but which would move freely by a side pressure. The form and dimensions of this device are shown in Fig. 13. As soon as the brick is broken, the knife edges are thrown outward and the hammer swings freely through. With the aid of these "free knife-edges" bricks were tested with good results.

Owing to the low resilience of a brick compared with its weight, it was found advisable to raise the hammer no higher than was necessary to break the brick. A higher drop usually showed a higher resilience. It is probable that the values given in Table No. 6 are higher than would be obtained could the error due to inertia be entirely eliminated. It is hardly safe to accept these results in comparing bricks, unless they be of the same dimensions.

TABLE No. 6.—Resilience of Vitrified Paving Brick.

All broken on a span of 7 ins.

Where made.	Number of lot.	Depth in inches. h.	Width in inches. b.	Weight of brick in pounds. W.	Experiment Nos.	Number of tests.	Resilience per cubic inch in inch-pounds. R_1
Glen Carbon, Ill...	2	2.6	3.7	6.7	531-536	6	1.43
Galesburg, Ill	3	2.6	3.9	7.1	564-569	5	2 64
Kansas City, Mo...	4	2.5	3.8	6.8	539-544	5	1.00
Galesburg, Ill.....	5	2.6	4.0	6.9	545-550	6	1.54
Canton, O.........	6	2.5	3.9	6.8	551-557	6	2.09
Alton, Ill	7	2.5	3.8	6.5	558-563	6	1.25
Glen Carbon, Ill....	8	3.0	3.8	8.1	570-575	6	2.19
Athens, O..........	9	3.3	4.0	9.5	576-581	6	3.26*

* This high value is probably due, in part, to the greater weight.

Table No. 7 shows the results of a few tests of red brick. The comparative values obtained from soft and hard bricks are as might be expected. The familiar test of striking two bricks together in the hands is a crude impact test, and, in experienced hands, probably determines the comparative toughness of the brick with some accuracy.

Table No. 17 gives a comparison of the values obtained with different materials, tested in the manner described. They are classed as brittle materials because they can be tested in the same way as cast iron, and do not require special treatment, as do wrought iron and steel. The table gives a good rough idea of the comparative value of these materials under impact. The values given in the last column are the mean of several tests in each case. They should not be taken as typical, as the samples were taken from materials at hand and may not be truly representative.

Tests of Tough Materials.

Having now dealt more or less effectively with the brittle materials, a class that presents greater difficulties must be considered. How, for example, shall the ultimate resilience of a sample of wrought iron be determined ? If an attempt is made to break a rectangular bar of soft iron, it will only be bent. To break such a bar successfully, it must first be nicked. A nicked bar can be broken, and the resilience to be overcome is but little more than that of the metal lying close to the nick.

TABLE No. 7.—Resilience of Red Brick.

All broken on a span of 7 ins.

Kind of brick.	Number of lot.	Dimensions of Brick in Inches.			Weight of brick in pounds. W.	Experiment Nos.	Number of tests.	Resilience per cubic inch in inch-pounds. R_1.
		l.	h.	b.				
Face brick............	2	8.5	2.4	4.1	5.4	687–691	5	0.26
Common, hard burned.	3	8	2.2	3.9	5.1	692–695	4	0.30
Common, soft........	5	8.5	2.2	4.2	5.2	708–713	6	0.10

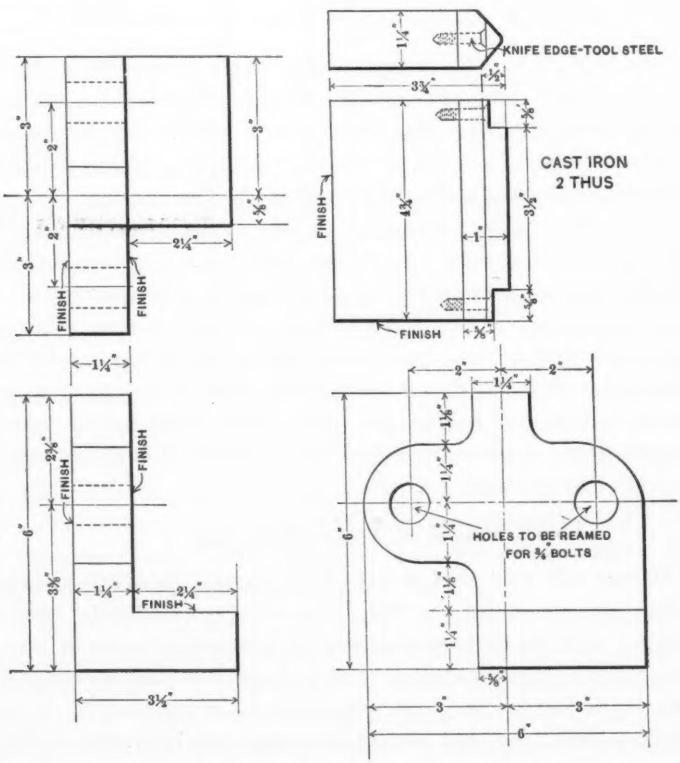

Figure 13.

TABLE No. 8.—Nicked Cast-Iron Bars.

Resilience per square inch.

Number of melt.	Experiment Nos.	Fig. No.*	Depth of section at nick in inches. h.	Width of section at nick in inches. b.	Number of tests made.	Resilience in inch-pounds per square inch of section at nick. R_2.	Resilience in inch-pounds per cubic inch of rectangular bars (rough) from same melt. R_1
3....	210-214	7	.5	1.0	5	49.5	11.4
3....	205-209	7	1.0	1.0	5	83.8	11.4
4....	272-275	9	.5	.9	4	81.6	11.8
4....	268-271	9	.75	.9	4	91.4	11.8
4....	264-267	9	1.0	.9	4	100.7	11.8

* Figure No. giving shape of nick (see Figs. 7 to 11).

N. B.—All bars 2 ins. x 1 in. All nicked bars broken edgewise, on 12-in. span. Weight of each bar about 6.4 lbs.

For want of some better method, the author adopted the plan of using a nicked bar for testing soft iron and steel, and determining the ultimate resilience per square inch of cross-section at the nick. If the nick is deep enough to cause the bar to break off short, and is always

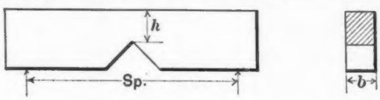

FIG. 7

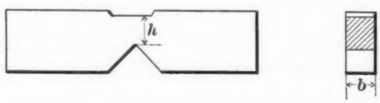

FIG. 8

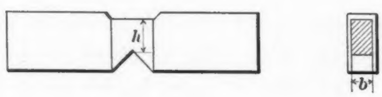

FIG. 9

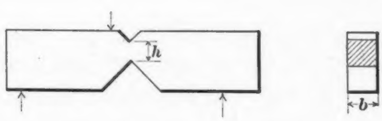

FIG. 10

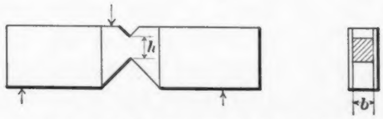

FIG. 11

of the same form, it would seem that the resilience should be in some degree proportional to the area of the reduced section. If, furthermore, the reduced section be always of the same depth, the resilience should be directly proportional to the area.

TABLE No. 9.—NICKED WOODEN BARS; LOT No. 3.

Resilience per square inch.

Experiments Nos. 313 to 375. All bars shaped as shown by Fig. 8, with depth of about $\frac{3}{4}$ in. at nicked section. Depth, $1\frac{3}{4}$ to 2 ins. at ends. Width of bars, $\frac{7}{8}$ to $1\frac{3}{4}$ ins., when not shown in second column. Span, 8 ins. These tests were made without shims, to prevent denting.

KIND OF WOOD.	Width of section at nick, in inches. b.	Weight of bar in pounds. W.	Number of tests made.	RESILIENCE IN INCH-POUNDS PER SQUARE INCH OF SECTION AT NICK. R_2. Maximum.	Minimum.	Average.
White pine	....	....	4	221	84	129
Ash	....	....	4	203	161	172
Cherry	.9	.38	4	299	118	216
Poplar	....	....	4	255	168	222
Red cedar, No. 1	1.0	.49	2	235	215	225
" " No. 2	1.7	.85	2	86	85	85
Gum	1.0	.44	4	299	....	247
Cypress, No. 1	1.7	.52	2	....	225	250
" No. 2	.9	.26	2	87	69	78
Chestnut	1.1	.44	6	432	199	306
Yellow pine	....	....	4	447	229	322
Black walnut	.9	.44	4	420	235	328
Maple	.9	.43	3	574	432	516
White oak	....	....	4	650	438	546
Oak, No. 2	....	....	4	500	....	419
Locust*	1.0	.56	6	690	566	633
Hickory*	1.1	.73	6	1 418	1 118	....

* The results in these remarkably tough woods are not strictly comparable with the others, on account of tearing out of the extreme fiber.

Figs. 7 to 11 show the different forms of nick that were used in the experiments. Each form of nick is designated by a figure number, so that it may be referred to in the tables; the numbers are those used in the department records. The order of these figures shows the results of the experience gained in these tests.

The first timber tests were made with bars like Fig. 7. The form shown in Fig. 8 was then tried in order to reduce the chances of longitudinal splitting. In Fig. 9, the section is diminished by planing the sides. Fig. 10 was found to give better results with very tough wood or metal. Fig. 11 is the same as Fig. 10, but with the section reduced as in Fig. 9. In the last two forms, the hammer strikes the bar at the side of the smaller nick.

Table No. 8 shows the results of nicked tests made with cast-iron. The values given in the last column show that the metal was all of equal toughness. The observed values, given in the column next

TABLE No. 10.—NICKED WHITE OAK BARS.

Effect of shields or shims at knife-edges.

All bars of straight-grained white oak of same quality. Bars nicked as shown in Fig. 10. Depth of section at nick (h) = 0.8 ins. Width of section (b) = 1.7 ins. Size of bar at ends = 1.75 ins. square. Weight of bar = 0.88 lb. Span, 8 ins.

	Experiment Nos.	Number of tests.	RESILIENCE R_2. Maximum.	Minimum.	Average.
With shims.......	450–455	6	430	301	343
Without shims...	456–461	6	505	278	410

to the last, indicate that the resilience per square inch of section is not constant for varying depths of section.

Table No. 9 shows the results of tests with different kinds of wood. The values for the resilience shown by this table are probably somewhat high on account of loss by denting the wood. Table No. 10 shows some tests made to learn how much loss of energy was occasioned by denting. From these results it would appear that the loss in this way was considerable, and that the wood should always be protected by shields or shims, at the knife-edges. The shims used were thin strips of tempered steel about ½ in. wide. They were laid flatwise between the knife-edge and the specimen. All the later experiments were made with the specimens protected from the knife-edges in this way.

Table No. 11 shows the results of tests made to determine the effect of increasing the depth of the nicked section. The results indicate that the resilience of a nicked bar is not directly proportional to the area of the nicked section. The variation is in the same direction as it was in the cast-iron bars recorded in Table No. 8.

The nick shown by Fig. 10, which was used in the tests shown in Tables Nos. 10, 11 and 12, was found to be the most satisfactory form for tests of wood. With this nick there is seldom any longitudinal splitting, which would destroy the value of the test. Table No. 12 shows tests of white and yellow pine and white oak, made with this form of nick. Shims were used in these tests, so that they may be considered as made in a more approved manner than the tests of Table No. 9. It is interesting to compare these timber tests with those made by Professor Thurston (see Table No. 21).

TABLE No. 11.—NICKED YELLOW PINE BARS.

Resilience per square inch.

All bars of same lot of straight grain lumber. Bars nicked as shown in Fig. 10. Width of section (b) = $1\frac{1}{2}$ ins. Size of bar at ends 2 x $1\frac{1}{2}$ ins. Weight of bar = 0.75 lbs. Bar protected by steel shims at knife-edges. Span, 8 ins.

Depth of section at nick. h.	Experiment Nos.	Number of tests.	Resilience in Inch-Pounds per Square Inch of Section. R_2. Maximum.	Minimum.	Average.
.66	523–530	8	410	124	312
.88	496–503	8	525	211	447

TABLE No. 12.—NICKED WOODEN BARS; LOT No. 4.

Resilience per square inch.

All bars $1\frac{3}{4}$ to 2 ins. deep at ends. All bars nicked as shown in Fig. 10. Bars protected by shims. Span, 8 ins.

Kind of Wood.	Depth of section at nick. h.	Width of beam in inches. b.	Weight of beam in pounds. W.	Number of tests made.	Resilience in Inch-Pounds per Square Inch of Section. R_2. Maximum.	Minimum.	Average.
White pine......	.88	.83	.35	7	223	90	161
Yellow pine.....	.66	1.5	.75	8	410	124	312
White oak......	.80	1.7	.88	6	430	301	343

TABLE No. 13.—NICKED BRONZE BARS.

Resilience per square inch.

Bronze containing 85% of copper. All bars from same melt (lot No. 2), and 2 ins. x $\frac{1}{2}$ in. at ends. All broken edgewise on 12 ins. span.

Experiment Nos.	Figure number.	Depth of section at nick in inches. h.	Width of section at nick in inches. b.	Weight of bar in pounds. W.	Number of tests made.	Resilience in Inch-Pounds per Square Inch of Section at Nick. R_2. Maximum.	Minimum.	Average.
394–399..	7	1.00	.50	4.22	3	1 305	1 192	1 252
		.50	.50	4.13	3	1 302	884	1 087
473–478..	9	1.00	.38	4.31	3	1 205	1 087	1 147
		.32	.38	4.00	3	769	581	673

NOTE.—Ultimate strength, 27 730 lbs. per square inch. 6.9% elongation in 8 ins. Tensile resilience by gradual load, 1 573 in.-lbs. per cubic inch.

TABLE No. 14.—Nicked Plow-Steel Bars.

Resilience by impact and by gradual load.

All bars nicked as shown in Fig. 7, and broken edgewise on a span of 12 ins. All bars 2 ins. x $\frac{1}{4}$ in. Weight of one bar = 1.6 lbs.

By Impact.			By Gradual Load.	
Depth of section at nick in inches. h.	Number of tests made.	Resilience in inch-pounds per square inch of section at nick. R_2.	Number of tests made.	Resilience in inch-pounds per square inch of section at nick. R_3
.50	4	2 115	4	1 527
.75	4	1 625	3	1 133
.75	..	.....	1	1 460
.25	4	1 913	..	.....

Note.—All from lot No. 1. Ultimate tensile strength, 83 720 lbs. per square inch. Elongation, 20.3% in 7⅝ ins. Ultimate tensile resilience by stress diagram, 15 000 in.-lbs. per cubic inch, gradual load.

Table No. 13 shows twelve experiments with bronze. Here, again, it will be noticed that the resilience per square inch increases with the depth h, as it did in the case of cast-iron and wood.

Table No. 14 shows a comparison of impact and gradual loading on nicked bars of plow-steel. The gradual load tests were made in an ordinary transverse testing machine; the loads and corresponding deflections were observed and plotted, and the resilience was taken from the diagram. It will be noticed that the resilience by impact is about one-third greater than the resilience by gradual load. The difference is nearly as great as was observed in rectangular bars of cast iron (see Table No. 1). Table No. 14 shows also that the resilience per square inch does not increase with a greater depth of section, as was observed in nicked bars of cast-iron, wood and bronze. In the plow-steel tests it is found that the greatest depth gives the least unit resilience, quite the opposite of what might have been expected.

Table No. 15 shows a number of experiments with steel and iron. The values of resilience given in the last column show quite a range. The tests were made with different forms of nick, and due allowance should be made for this in making comparisons. In making these experiments it was found that with very tough metal the bar should be nicked on both edges, to insure a clean break and uniform results. Some of the lots of steel were tested for tensile strength and elonga-

TABLE No. 15.—Nicked Iron and Steel Bars.

Resilience per square inch.

Metal.	Number of melt.	Number of tests made.	Fig. No.	Depth and thickness of bar before nicking, in inches.	Dimensions. Span in inches. L.	Dimensions. Depth of section at nick, in inches h.	Dimensions. Width of section at nick, in inches. b.	Resilience in inch-pounds per square inch of section, at nick. R_2.
W. I..	2	3	8	2 x ¼	12	.18	.25	1 700
	1 A	3	9	2 x ⅜	12	.20	.20	2 150
M. S..		3	7	1 x 1	12	.24	1.00	640
	1 B	4	7	1 x 1	12	.37	1.00	600
		3	10	2 x ¾	8	.25	.75	773
M. S..	3	4	11	2 x ¾	8	.25	.62	629
		4	11	2 x ¾	8	.25	.37	937
		4	10	2 x ¾	8	.50	.75	661
	1 A	3	9	2 x ⅜	12	.20	.20	1 790
	1 B	3	7	1 x 1	12	.37	1.00	460
		3	7	1 x 1	8	.39	1.00	2 400
	2 A	4	7	1 x 1	8	.25	1.00	3 300
		4	9	1 x 1	8	.25	.75	3 200
S. S...		4	9	1 x 1	8	.25	.37	3 600
		4	8	2 x ⅜	8	.25	.37	935
	2 B	4	8	2 x ⅜	8	.50	.37	925
		4	9	2 x ⅜	8	.25	.20	1 160
		3	10	2 x ⅜	8	.50	.37	1 665
	2 C	3	10	2 x ⅜	8	.25	.37	1 647
		3	11	2 x ⅜	8	.25	.20	1 642
S. S...	3	4	10	1½ x ¾	8	.25	.75	1 285
N S. .	1	4	10	2 x ¼	8	.25	.25	2 600
F. S. .	1	4	10	2 x ¼	8	.25	.25	3 300
		3	10	2 x ⅜	8	.50	.37	2 762
C. S. .	2	2	10	2 x ¾	8	.25	.37	1 770
		2	10	2 x ¼	8	.50	.25	2 576
		2	10	2 x ¼	8	.25	.25	1 709

Explanation.—Metal: W. I. = wrought iron; M. S. = medium steel; S. S. = soft steel; C. S. = cast steel; N. S. = nickel steel; F. S. = fluid compressed steel.

TABLE No. 15a.—Tensile Tests of Iron and Steel.

Kind of metal.	Lot.	Ultimate tensile strength in pounds per square inch.	Percentage of elongation.	Ultimate tensile resilience in inch-pounds per cubic inch by gradual load.
Wrought iron...........	2	49 430	16.6 in 7 ins....	7 375
Medium steel	1 A	85 300	23.3 in 7.6 " ...	......
Medium steel	1 B	80 200	21.9 in 8 " ...	......
Soft steel..............	1 A	69 100	27.5 in 7.6 " ...	......
Soft steel..............	1 B	61 900	25.5 in 8 " ...	......
Nickel steel	1	72 680	27.5 in 8 " ...	......
Fluid compressed steel..	1	91 260	18.9 in 8 " ...	......

TABLE No. 16.—NICKED ALUMINUM BARS.

Resilience per square inch.

All bars 8 ins. long between supports. Experiments Nos. 740–762.

Depth and width of bar at ends in inches.	Fig. No.	Size of Section at Nick in Inches. Depth. h.	Width. b.	Weight of bar in pounds. W.	Number of tests made.	Resilience in inch-pounds per square inch of section at nick. R_2.
1¼ x 1¼	10	.25	1.25	1.44	4	468
	10	.37	1.25	1.45	4	600
	11	.37	.75	1.41	3	513
2 x 1¼	10	.25	1.25	2.06	4	530
	10	.50	1.25	2.13	4	579
	11	.50	.75	2.07	3	519

NOTE.—Ultimate tensile strength, 16 750 to 19 970 lbs. per square inch Elongation, 1½ to 3½% in 8 ins. Ultimate tensile resilience by stress diagram, 15 000 in.-lbs. per cubic inch, gradual load.

tion. The results of these tests are given in Table No. 15A. From the tests of Table No. 15, it will be noticed that there seems to be no definite relation between the depth of the section and the resilience obtained.

Table No. 16 gives the records of tests made with bars of aluminum. The metal was of the kind used in making bicycle frames. An analysis showed 98.05% of aluminum. A tensile test showed 16 750 to 19 970 lbs. per square inch ultimate strength, and 1½ to 3½% elongation, in 8 ins. The specific gravity of the metal was 2.764. In these tests a greater unit resilence with a greater depth of section may again be observed.

Table No. 18 gives a comparison of the tests made with different materials. The values cannot be taken as typical in all cases. It will be noticed that the tool-steel, which was of good quality, tested but little better than cast-iron, and was much below the oak in value. High-grade steel is known to have little shock-resisting capacity. In low-grade steels, or steels low in carbon, it is a commonly accepted theory that a high percentage of phosphorus makes steel brittle under impact.* It may be from such a cause that some of the medium steel tested gave such low results.

* Johnson's "Materials of Construction," pp. 166 and 167.

TABLE No. 17.—RESILIENCE OF BRITTLE MATERIALS.

Resilience in inch-pounds per cubic inch. All tests made with rectangular beams, struck in the center and broken by a single blow.

Material.	Resilience. R_1. Max.	Min.	Av.	Material.	Resilience. R_1. Max.	Min.	Av.
Cast-iron, rough	18	10	11.5	Common brick, soft	......	......	.10
" " planed	22	19	21	Fire "	......	......	.44
Vitrified paving brick	3	1	1.6	Terra cotta, red	......	......	.33
Face brick, red	......	......	.26	"Granitoid"*	.30	.15	.20
Common brick, hard	......	......	.30				

* A composition of Portland cement and crushed granite, much used for sidewalks.

TABLE No. 18.—RESILIENCE OF TOUGH MATERIALS.

Resilience in inch-pounds per square inch of section at nick. All tests made with rectangular beams, nicked at the center and broken by a single blow.

Material.	Resilience. R_2. Max.	Min.	Av.	Material.	Resilience. R_2. Max.	Min.	Av.
Cast-iron	......	......	81.6	Wrought-iron	......	......	1 700
White oak	......	......	343	Plow-steel	......	1 625	1 870
Tool-steel	......	......	134	Medium-steel	2 150	600	900
Aluminum	......	468	500	Soft-steel	3 600	460	1 900
Bronze No. 85	......	673	870	Cast-steel	......	1 709	2 000

From the values of resilience for materials given in Tables Nos. 17 and 18, taken together with the known specific gravity of these materials, a comparison may be made to show the relative resilience of a given weight of the different materials. Such a comparison made by the author showed that oak is the toughest material of all, where equal weights are taken. The materials may be arranged in the order of their toughness for a given weight as follows: White oak, tough steel, wrought iron, aluminum, bronze, tool-steel, cast-iron, vitrified brick and hard brick.

TABLE No. 19.—Impact Test.

St. Louis, February 24, 1897.

Office of Water-Works Extension. Specimen of cast iron taken from Shickle & Harrison. Specials—Pump Main No. 8. Tested for cross-breaking resilience, with results herewith appended. Lot No. 6.

Experiment No.	Bar No.	Initial fall of hammer in inches. F.	Rise after blow in inches. S.	Correction for friction in inches. C_1	Length between supports in inches. L.	Depth of beam. h.	Width of beam. b.	Volume of bar in cubic inches. $V = Lhb$.	Weight of bar in pounds. W.	Correction for inertia of bar in inches. $= .011$ W. S. C_2.	Effective fall of hammer. $H=F-(S+C_1+C_2)$.	Total resilience in inch-pounds. $R = 103$ H	Resilience per cubic inch in inch-pounds. $R_1 = \frac{103 \text{ H}}{\text{V}}$	Remarks.
582	1	6	3.24	0.17	12	1.05	2.07	26.082	7.75	.28	2.31	237.93	9.12	
583	2	4	0.64	0.13	12	1.09	2.02	26.420	....	.05	3.18	327.54	12.40	
584	3	4	0.85	0.13	12	1.05	2.05	25.830	....	.07	2.95	303.85	11.76	
586	4	4	1.38	0.13	12	1.02	2.05	25.092	....	.12	2.37	244.11	9.73	{ Small flaws on tension and comp. side.
587	5	4	0.81	0.13	12	1.04	2.00	24.960	....	.07	2.99	307.97	12 34	
588	6	4	1.55	0.14	12	1.00	2.03	24.360	....	.13	2.18	224.54	9.22	
												Av.....	10.76	

TABLE No. 20.—Resilience of Beams.

R = Resilience in inch-pounds of a beam 1 in. square and 12 ins. between supports.

Kind of material.	Value.	Kind of material.	Value.
Cast-iron	81	Oak, English	78.4
Slate	3.2	" Canada	71.5
York paving	0.96	Pine, pitch	70.7
Ash	127.6	" red	58.7
Cedar	100.0	....	....

Note.—The above values were taken from Table No. 67 of Box on "Strength of Materials."

TABLE No. 21.—Relative Torsional Resilience.

Kind of wood.	Value.	Kind of wood.	Value
White pine	1.00	Yellow pine	3.87
Spruce	1.50	Black walnut	3.95
Red cedar	1.61	Locust	5.80
Spanish mahogany	1.65	Oak	6.60
Ash	2.25	Hickory	6.90
Chestnut	2.40	....	....

Note.—The above table was taken from Thurston's "Materials of Engineering." These tests were made with gradual load.

From the values of resilience shown in Tables Nos. 17 and 18, taken together with the average cost of these materials, a comparison may be made to show the relative cost for a given amount of ultimate resilience. Such a comparison, made by the author, shows that oak is the cheapest material for a given resilience, while tool steel is the most expensive of the lot. The following is the order, with the cheapest first: Oak, tough steel, wrought iron, vitrified brick, cast-iron, hard brick, bronze, aluminum and tool-steel. These comparisons may have some value as suggestions, until such time as more exhaustive experiments are made.

Tables Nos. 21 and 22 were taken from well-known authorities, and are given for comparison with the results of the other experiments. Both of these tables present values of resilience by gradual loading.

Conclusions.

The conclusions are: *First*, in the case of brittle materials, definite values for resilience may be obtained.

Second, in the case of tough materials like wrought iron, definite relative values for resilience of materials of the same class may be obtained.

This latter conclusion indicates that it may be specified that steel shall show a certain ultimate resilience per square inch, with a given form of nicked test bar. Should this requirement prove satisfactory in practice, it may eventually be possible to dispense with chemical tests of steel for structural purpose.

When the proper values of resilience under impact have been determined for structural materials, designers will be able to act with more intelligence in planning structures exposed to live loads and to shocks. They will be able to substitute iron or stone for wood in certain cases with greater assurance of safety. The study of resilience will also lead to better designing in other ways. Useless material in a structure or member will generally decrease the resilience, which fact is already well known but frequently lost sight of. The general use of resilience tests would serve to keep such facts in mind, and make them more commonly understood.

It is with the idea of encouraging the practical use of impact tests that the results of these experiments are offered to the Society.